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ARMY PRELIMINARY EVALUATION OF THE AH-1G TRACTOR TAIL ROTOR MODIFICATION

FINAL REPORT

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JUNE 1969

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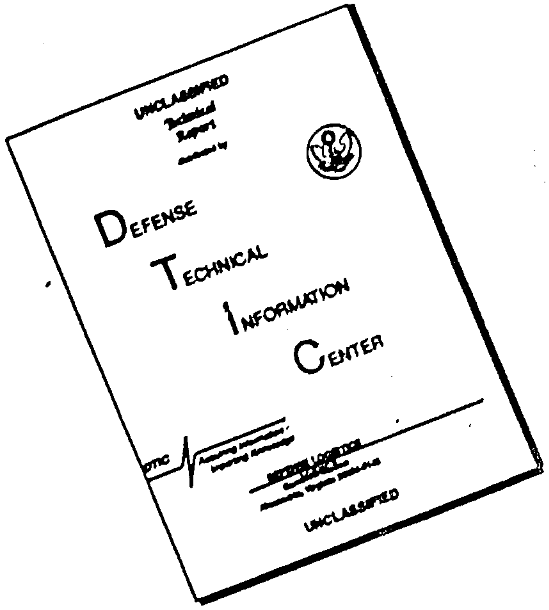

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FINAL REP[redacted]RT, 11 Jul 68 - Jan 69,

(10)

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ABSTRACT

The Army Preliminary Evaluation of the tractor tail rotor modification on the AH-1G helicopter was conducted in California at Bishop Municipal Airport (4000 ft) and Coyote Flats (9500 ft) during the period 9 August to 31 August 1968. This test was conducted to confirm the results of the feasibility tests with the proposed final configuration for this modification and also to evaluate both the performance in hover and level flight and the handling qualities throughout the flight envelope. This modification provides an increase in the usable in-ground-effect (IGE) operating envelope and improves the directional control characteristics while maneuvering. The test showed good agreement with the results of the earlier feasibility tests. The maximum safe IGE maneuvering envelope for the tractor tail rotor AH-1G was determined and defined by those conditions of gross weight and density altitude where a 10-percent directional control margin was available in the critical azimuth in a 15-knot wind. Using the same criteria for the standard AH-1G configuration, the difference due to the improved directional control with the tractor tail rotor is equivalent to an additional 1500 pounds payload at the same density altitude. However, the standard AH-1G operator's manual contains specific wind azimuth and gross weight restrictions which are less severe than the criteria defined above. With these operational restrictions applied to the standard AH-1G, the difference in operating weight for the two configurations is considerably less than 1500 pounds; however, the safety margin is reduced. It must be emphasized that the tractor tail rotor does not solve the basic directional control problem of the AH-1G. The performance capability of the AH-1G weapon system cannot be realized because of the inadequate directional control. The power loads in the tail rotor drive system are still high with the tractor tail rotor. Steady state power loads recorded in the tail rotor drive were near the revised maximum allowed of 165 shaft horsepower (shp). Transient peaks up to 225 shp were recorded during maneuvers. The performance and handling qualities in forward flight up to never-exceed airspeed (V_{NE}) showed no significant difference between the standard and tractor tail rotor configurations.

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INTRODUCTION

BACKGROUND

1. Results of the US Army Aviation Systems Test Activity (USAASTA) Phase B testing showed that the directional control power was inadequate within a large portion of the proposed low speed in-ground-effect (IGE) maneuver envelope for the AH-1G helicopter. These tests had been conducted with a 20-degree tail rotor blade angle rigging for full left pedal (ref 2, app I). The tail rotor was rerigged to 23 degrees to provide more directional control and flight tested by the contractor. With the increased maximum blade angle more directional control was available, but the high power loads in the tail rotor drive system (up to 290 shaft horsepower (shp)) caused unacceptable damage to the tail rotor drive system components. Equally important, the increased control did not solve the problem of directional control instability at certain conditions of relative wind within the required operating envelope. Later, a revised tail rotor blade configuration was tested with similar results. The contractor then conducted tests to define the maximum thrust capability of the tail rotor and the corresponding horsepower required to develop it as a function of the tail rotor blade angle. A rigging of 19 degrees was determined to require approximately 230 shp when developing maximum thrust. Limited tests were then conducted by the contractor and USAASTA to define the safe operating envelope and provide guidance for the operators (ref 3, app I). These tests proved that even at the lowest usable mission weight and low altitudes, large areas of uncertain and inadequate directional control existed. Various warnings and operating restrictions were imposed on the AH-1G as a result. Despite these warnings and restrictions, there are continuing reports from the operating units of incidents and accidents resulting from loss of directional control while maneuvering in the parking or loading areas. The reports also indicate that the restrictions on weight significantly reduce the combat effectiveness of the helicopter. To eliminate these restrictions, a modification was then proposed by the contractor using the same gear boxes, tail rotor blades, most control components and a tractor type tail rotor configuration. The modification is fully described in reference 5, appendix I, BHC Engineering Change, Proposal AH-1G 350. Early tests were conducted by the contractor and USAASTA within the low speed maneuver envelope to evaluate the feasibility of the tractor tail rotor configuration as a solution to the AH-1G directional control problem (ref 4, app I). These tests indicated a larger operating envelope was possible and the directional control instability at or near control limits was largely eliminated. Further testing by the contractor to clear the modification throughout the complete speed and maneuver envelope was completed in July 1968. On 19 July 1968

the US Army Aviation Systems Command (USAAVSCOM) directed USAASTA to conduct an Army Preliminary Evaluation (APE) of the tractor tail rotor on the AH-1G helicopter (ref 7, app I). The test sites were selected to provide a basis for comparison with the results of the previous tests and evaluate the maneuver envelope at higher altitudes.

TEST OBJECTIVES

2. The test objectives of the Army Preliminary Evaluation were as follows:

a. A quantitative and qualitative evaluation of the high speed handling qualities of the AH-1G and the tractor tail rotor configuration.

b. A quantitative and qualitative evaluation of the handling qualities in the low speed envelope up to the maximum usable density altitude.

c. A quantitative evaluation of the hover and level flight performance of the AH-1G with the tractor tail rotor.

DESCRIPTION

3. The test aircraft, S/N 66-15283, is the thirty-ninth AH-1G produced by the Bell Helicopter Company (BHC). It was designed specifically for the armed role. It is a conventional helicopter with a narrow fuselage two-place tandem (gunner forward and pilot aft). The main rotor has two blades and a door hinge. The modified tail rotor resembles the standard except it is located on the right side of the vertical pylon and rotates in the opposite direction (counterclockwise). The rigging for full left pedal is a 19-degree tail rotor blade angle, the same as used for the standard configuration. The controls are conventional in the aft (pilot) cockpit. The cyclic and collective are short, side-arm type in the front (gunner) cockpit. The controls to the swashplate are positive mechanical with a dual, irreversible hydraulic boost system to reduce control forces. A magnetic-brake type, spring-feel system is provided for the cyclic and directional controls. A three-axes stability and control augmentation system (SCAS) is installed to improve the handling qualities. The elevator is mechanically linked to the longitudinal cyclic control to provide improved static longitudinal stability and larger center of gravity (cg) range. The helicopter is powered by a Lycoming T53L-13 turboshaft engine rated at 1400 shp. The engine is derated to 1100 shp at 314 rotor rpm due to main transmission torque limitations.

SCOPE OF TEST

4. The scope of this APE was limited by the time the aircraft was available to USAASTA fo~ testing. Two weeks for testing were allotted with an additional week for aircraft preparation and ferry flights. Although the AH-1G was not held to MIL-H-8501A in directional control at the time of acceptance, comparison of data results with the specification was made in the appropriate sections.

5. The flight restrictions which governed the conduct of this test were those defined in the operator's manual (ref 8, app I) with the following exceptions as stated in the safety of flight release (ref 6, app I):

a. Current limitations with gross weight on sideward and rearward flight and takeoffs and landings are rescinded for this aircraft and sideward and rearward flight limits for all gross weights and altitudes are 35 knots.

b. Rapid hovering turns and large, rapid directional pedal inputs should be avoided in order to preclude damage to the tail rotor gear boxes. Moderate turn rates of 30 deg/sec (90 degrees in 3 seconds) should not be exceeded. The abrupt arrestment of turns in excess of 30 deg/sec is prohibited.

c. If 175 shp is exceeded on the tail rotor drive shaft, an inspection is required in accordance with AMSAV-SDO message 10-4, 24 October 1967.

6. Eighteen test flights were flown during this test for a total of 17.6 hours. In addition, 22.4 hours were flown ferrying the aircraft to the test sites and returning it to Arlington, Texas. Since Phase D testing with the standard AH-1G was in progress, similar tests were flown with it to provide comparison data.

METHOD OF TEST

7. Performance and stability and control were evaluated using standard engineering flight test techniques for both the hover and level flight conditions.

8. Paced flight tests were conducted in ground effect (IGE) at the 4000- and 9500-foot sites. A calibrated ground pace vehicle was used for speed reference and the heading was varied in even increments to cover all relative wind azimuths at each speed. Wind speed and direction were continuously monitored and this was correlated

with the data points by radio. Control positions, attitudes, rates, tail rotor blade angle and tail rotor shaft torque were recorded for each stabilized point. Data points were taken up to the control limit or 35 knots, whichever occurred first.

9. The directional control capability was evaluated by making rapid, full pedal control inputs from stabilized flight conditions where left pedal remaining was less than 10 percent.

10. Arrestment of hover turn rates was evaluated by establishing steady hover turn rates to the right in calm conditions and rapidly applying full left pedal until the turn rate was zero. Yaw rate, pedal input and tail rotor shaft torque were recorded.

CHRONOLOGY

11. The chronology of this program is as follows:

Test directive received	19 July	1968
Test helicopter received	9 August	1968
Flight test commenced	15 August	1968
Flight test completed	31 August	1968
Test helicopter returned to contractor	3 September	1968
Preliminary report submitted	25 October	1968

RESULTS & DISCUSSION

PERFORMANCE

Hover Performance

12. Tethered hover tests were conducted to determine the hover performance of the AH-1G tractor tail rotor configuration. The results are shown in figure 1, appendix II. Comparison of the hover performance for the tractor and the standard tail rotor configurations under the same conditions showed some difference in power required. The significance of the difference can not be accurately determined due to the lack of an engine calibration for the tractor tail rotor test aircraft.

Level Flight Performance

13. The results of the level flight tests are presented in figures 1 through 4, appendix II. The tests were conducted at a forward center of gravity (cg) with four XM159 rocket launchers (Hog Configuration). Gross weight and density altitude were varied to provide a range of C_T for best comparison with standard AH-1G Phase D data. The comparison showed some difference in power required for the two configurations. This difference may or may not be significant depending on the error in the engine torque system of the test aircraft. Further testing with a calibrated engine would be required to accurately determine performance differences.

STABILITY AND CONTROL

Control Trim Positions

14. The directional control pedal requirement during hovering flight was recorded at each data point to determine where the operating envelope was limited by lifting thrust capability or directional control available. Two skid heights, 5 and 100 feet, were used to provide the data for comparison with the standard AH-1G, Phase D test results. Because of unreliable load cell readings during the tethered hover test at 10,500 feet, the thrust coefficient (C_T) data was not available; however, power and pedal position data were recorded. An extrapolation of the power coefficient (Cp) versus C_T curve obtained from hover tests at 5500 feet H_D was used to derive C_T values for the measured power data. The derived C_T values were then plotted with pedal position (fig 5, app II).

15. The control trim positions for trimmed level flight were obtained during the level flight performance tests. The data are presented in figure 6, appendix II. The curves are similar to those of the standard AH-1G.

Static Lateral and Directional Stability

16. The static lateral and directional stability tests were conducted at three trim airspeeds with fixed collective. The sideslip angle was increased in increments from zero to the limit in both directions. The quantitative data are presented in figure 7, appendix II. The static lateral and directional stability is positive and increases with increasing airspeed. These results are similar to those of the standard AH-1G Phase D data and comply with paragraph 3.3.9 of MIL-H-8501A.

Dynamic Stability

17. Following one-inch pulse inputs, the dynamic stability characteristics of the AH-1G tractor tail rotor were qualitatively evaluated. The results showed no significant difference between the tractor and standard configurations (PRS A2 for SCAS ON, PRS A3 for SCAS OFF).

Controllability

18. Lateral and directional controllability tests were conducted in hover and forward flight. Quantitative data are presented in figures 8 through 19, appendix II. Table 1 shows the directional response results at various gross weights, altitudes, cg and trim airspeed for 0.75-inch inputs.

19. The maximum yaw displacement recorded for a 1-inch pedal input was well below the maximum of 50 degrees allowed in paragraph 3.3.7 of MIL-H-8501A. The response to directional control inputs is equal in both directions for the tractor tail rotor. For the same test conditions, the standard AH-1G directional response to the left is 6 deg/sec less than the rate to the right. The directional response characteristics in forward flight are similar for the two configurations.

Table 1. Directional Response.

324 rpm, Hover, Clean Configuration

	Gross Weight (lb)	Center of Gravity (in)	Density Altitude (ft)	Left Max Rate (deg/sec)	Left Max Accel (deg/sec^2)	Right Max Rate (deg/sec)	Right Max Accel (deg/sec^2)
SCAS OFF	8000	197.4	4,200	16.5	22	16	23.5
	8680	193.5	5,660	16.5	22	16	23.5
	7375	195.0	10,660	16.5	22	16	23.5
SCAS ON	8000	197.4	4,200	18	26	18.5	25
	8680	193.5	5,660	18	26	18.5	25
	7375	195.0	10,660	18	26	18.5	25

324 rpm, Level Flight, Hog Configuration

	Gross Weight (lb)	Center of Gravity (in)	Density Altitude (ft)	Airspeed (KCAS)	Left Max Rate (deg/sec)	Left Max Accel (deg/sec^2)	Right Max Rate (deg/sec)	Right Max Accel (deg/sec^2)
SCAS OFF	7880	200	5,220	105	8	23	8.2	23.8
	7805	200	5,370	128	8	23	8.2	23.8
	9065	196.8	6,120	95	6.5	15	9	20
	8875	197.5	6,220	118	6.5	15	9	20
SCAS ON	7880	200	5,220	105	12.5	23	11.5	21
	7805	200	5,370	128	12.5	23	11.5	21
	9065	196.8	6,120	95	10.5	21	9	24
	8875	197.5	6,220	118	10.5	21	9	24

20. The maximum roll rate during a SCAS OFF lateral stick input of 1 inch was 21.5 deg/sec to the right and 20.5 deg/sec to the left, respectively, at a gross weight of 7705 pounds and 128 KCAS. At a gross weight of 8800 pounds and 118 KCAS, the rates were 23 deg/sec and 18 deg/sec. For SCAS ON 1-inch lateral inputs, the maximum roll rates were 14 deg/sec right and 15 deg/sec left at 7705 pounds and 128 KCAS. At 8800 pounds and 118 KCAS, the rates were 17 deg/sec right and 14 deg/sec left. There was no tendency to over-control during SCAS ON flight (PRS 2). For SCAS OFF flight, the roll control characteristics are degraded considerably at high speeds above 120 KCAS. The aircraft has a short-period roll oscillation, and the control characteristics are such that experience and practice are required to avoid PIO in roll with roll channel OFF (PRS 5).

Simulated Engine Failure

21. The aircraft behavior following a simulated engine failure was evaluated qualitatively at airspeeds up to V_{NE} at 6000 feet H_D. The tests indicate no noticeable difference in aircraft characteristics between the two configurations (PRS 4).

DIRECTIONAL CONTROL CAPABILITY

22. During the directional control capability tests, the yaw response of the aircraft at critical wind azimuth and speed conditions was qualitatively evaluated to determine the margin of directional control travel required for safe IGE maneuvering. Qualitative impressions were correlated with the time history records of several left pedal inputs from stabilized sideward flight conditions where less than 10 percent of the total travel was available. Three such time histories are presented in figures 46, 47 and 48, appendix II. As a result of these tests, a yaw response of 8 deg/sec in 1 second after the input is considered marginally adequate for this aircraft. Figures 10, 46, 47 and 48 show that an input of 10-percent pedal travel (0.5 in.) will produce a yaw response of at least 8 deg/sec in 1 second for all conditions tested. This margin, 10 percent of the directional control travel, is significantly less than that required to meet the requirements of paragraph 3.3.6 of MIL-H-8501A. The specification requires a margin of approximately 14 percent. This 4-percent difference, although small, results in a significant difference in the flight envelope. The envelopes shown in figure 20 would be reduced approximately 5 knots each. To achieve the specification yaw response, 5 degrees displacement at a gross weight of 9500 pounds at the critical azimuth and 35 knots would require a tail rotor thrust much greater than the capability of either the standard or tractor tail configurations on the AH-1G helicopter. In addition, the AH-1G is further limited in both configurations by

maximum power allowed in the tail rotor drive system. Thus, these directional control capability tests defined the maximum safe IGE maneuver envelope for the AH-1G with the tractor tail rotor installed.

23. The AH-1G, with either tail rotor configuration, does not meet the present specification criteria for IGE yaw control power and directional response at the maximum gross weight and 35 knots. The present specification is considered inadequate for both design and test purposes. The following are reasons for this consideration:

a. The criteria considers gross weight only with no allowance for the role (or category) of the helicopter, specifically not providing for very heavy helicopters.

b. The criteria describes a yaw displacement without considering the yaw rate and acceleration characteristics which are the pilot's cues and form the basis for his control inputs.

c. The criteria provides no minimum pedal travel margin. This must be considered along with total travel available, control sensitivity and the directional stability characteristics near the limit conditions. In this aircraft the minimum travel required is considered to be 0.5 inch.

PACED FLIGHT

24. Ground paced flight at selected azimuths and speeds was the test technique used to evaluate the IGE maneuver envelope. A calibrated ground pace vehicle was used as a speed and position reference. The speed was increased in 5-knot increments from 5 to 35 knots or until the control limit was reached. At each speed the relative wind azimuth was varied through 360 degrees by stabilizing on selected headings while maintaining a constant ground track over the runway. The skid height maintained during the tests was approximately 5 feet for all points. The test conditions flown with the tractor tail rotor and standard tail rotor configurations are summarized in tables 2 and 3, respectively. The test results are presented in figures 20 through 45, appendix II.

and standard tail rotor configurations are summarized in tables 2 and 3, respectively. The test results are presented in figures 20 through 45, appendix II.

Table 2. Test Conditions - Tractor Tail Rotor.

Configuration	Gross Weight (lb)	CG Location (in.)	Density Altitude (ft)	Rotor (rpm)
Heavy Scout	8420	192.3	4,685	324
Heavy Scout	8885	194.5	6,010	324
Heavy Scout	8235	193.2	10,240	324

Table 3. Test Conditions - Standard Tail Rotor.

Configuration	Gross Weight (lb)	CG Location (in.)	Density Altitude (ft)	Rotor (rpm)
Heavy Scout	8060	200.7	130	324
Heavy Scout	8060	200.8	570	314
Heavy Scout	8050	200.8	5,260	324
Heavy Scout	7250	195.4	11,100	324

25. The 10-percent directional control margin discussed in paragraph 22 was used to define the areas of inadequate directional control. To ensure acceptable yaw response for this aircraft in the most adverse condition, the IGE maneuver envelope was defined by those stable IGE flight conditions where at least 10 percent (0.5 in.) of the total pedal travel is available as a control margin. This criterion is more accurately based on a steady tail rotor blade angle of 16.1 degrees with the remaining 2.9 degrees available as margin, regardless of the SCAS yaw actuator position, since the pedal position for certain tail rotor pitch angles vary with SCAS actuator position. The tractor tail rotor aircraft was modified to provide sufficient pedal travel to ensure that the defined, maximum tail rotor blade angle (19 degrees) could be obtained in the most adverse position of the SCAS actuator. The BHC changes to the directional control linkage include a modified bell crank and new location of the stops. The bell crank affects a 12-percent gearing change

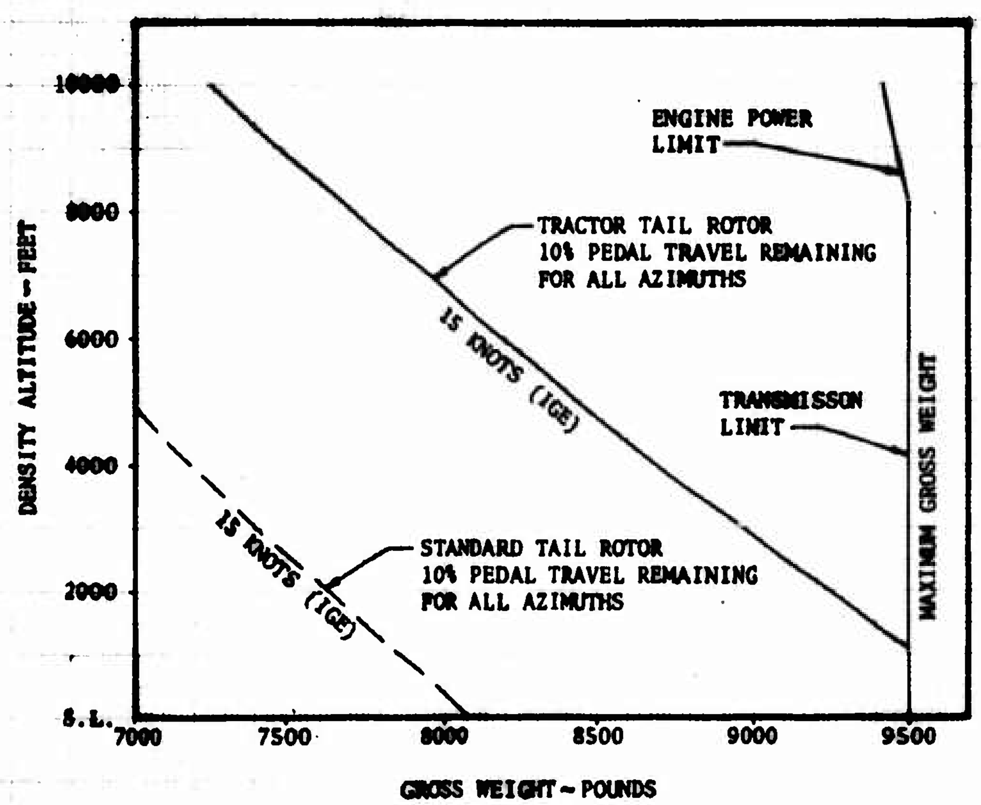
between the pedal position and the tail rotor blade angle. This provides a margin of 12-percent left pedal travel with the SCAS actuator nulled. This modification was not on the tractor tail rotor AH-1G used for the feasibility tests; consequently, those tests were based on a 12.5-percent control margin. The standard AH-1G used during these tests did not incorporate this yaw control geometry change either. All data for the tests with the standard AH-1G were taken with the SCAS yaw channel OFF. This was done for two reasons, to ensure that the full 19-degree tail rotor blade angle would always be available to the pilot and also to facilitate rapid data reduction, since no tail rotor blade angle data were available except by addition of the pedal and SCAS actuator positions. The data presented for the tractor tail rotor tests were also taken with the yaw SCAS OFF, although comparison tests were flown with the SCAS ON.

26. The critical wind azimuth for the tractor tail rotor configuration is a right crosswind; for the standard configuration it is ahead of a direct right crosswind, 60 to 65 degrees off the nose of the aircraft. At and just below translation speed, 12 to 14 knots, the standard configuration is unstable at most crosswind and tailwind headings. The control inputs required to maintain a heading ($\pm$10 degrees) are frequent and considerably larger than for other flight conditions. This instability results in marginal or inadequate directional control. The critical wind speed for the tractor tail rotor was 16 knots at a referred gross weight (W/σ) of 9680 pounds, 12 knots at 10,600 pounds and zero at 11,230 pounds. The comparable numbers for the feasibility test with this aircraft are 27 knots at 9400 pounds, 18 knots at 9800 pounds and 13 knots at 10,800 pounds. For the standard configuration with the yaw SCAS OFF and the 10-percent pedal-remaining criterion, the critical speed is 15 knots at 8100 pounds, 10 knots at 9450 pounds and 13 knots at 8240 pounds using 314 rotor rpm. During testing at Coyote Flats, directional control of the standard AH-1G was completely lost on one occasion, while it was possible to maintain control under the same conditions with the tractor tail rotor aircraft and accomplish more demanding maneuvers.

27. The paced flight tests showed the tractor tail rotor was much more stable and easier to control than the standard AH-1G at all relative wind azimuths up to the absolute control limit. The standard AH-1G required frequent and occasionally large pedal inputs to maintain heading in the critical conditions. This difference in the ease and accuracy of directional control is considered to be an important improvement offered by the tractor tail rotor. With consistent response and no areas of instability, the number of incidents and accidents due to loss of directional control with this aircraft should be reduced.

28. Figure A shows the IGE maneuvering flight envelope for the tractor and standard tail rotor configurations. The envelope is based on a control margin of 10-percent pedal travel at a critical azimuth in a 15-knot wind. For the same conditions and wind/azimuth restrictions, the tractor configuration shows a 1500-pound greater payload capability. For density altitudes above 1000 feet, the envelope shows a reduction of payload from the performance capability. At 5000 feet this difference is approximately 1100 pounds. If more demanding directional control criteria are used, the difference is even greater. The tractor configuration affords a significant improvement and should be considered as an interim modification for AH-1G helicopters. However, it must be strongly emphasized that this would only be a partial, expedient solution to the AH-1G directional control problem. A study and/or development program is required to provide a directional control system for the AH-1G which will not restrict the operational capability of the weapon system.

FIGURE A
SIDEWARD AND REARWARD FLIGHT ENVELOPE
GROSS WEIGHT CAPABILITY
ROTOR SPEED = 324 RPM



29. Qualitative takeoff tests using the modified level acceleration technique, where the power is increased gradually until the aircraft accelerates through translational lift (13-15 knots), were made with both AH-1G configurations. The results showed that 5 to 10 percent more left pedal was required as the aircraft reached translation than the pedal position required for a stable hover under calm conditions. This pedal travel requirement during takeoffs was the same for both configurations and varies with the rate of power increase during the maneuver. For moderate, comfortable rates of acceleration a control margin of 10 percent in a zero wind hover provides adequate directional control to perform a safe takeoff. The degree to which this control margin affects the hover performance capability is shown in figures 1 and 5, appendix II. However, the 10-percent directional control margin for maneuvering capability in a 15-knot wind required the more restrictive envelope shown in figure A.

ARRESTMENT OF HOVER TURN RATES

30. Tests were conducted to evaluate the effects of sudden arrestments at various steady hover turn rates up to 30 deg/sec and at different gross weights. Figure 51, appendix II, shows a maximum of 225 tail rotor shp which was recorded while arresting a right turn at a rate of 30.9 deg/sec with a gross weight of 9090 pounds. For a total time of 2.9 seconds the tail rotor drive system load was above 165 shp which was the revised maximum allowable. At a gross weight of 9100 pounds the arrested turn rate was 21.5 deg/sec (fig 50). The peak load was 204 shp and the time above 165 shp was 1.4 seconds. At a gross weight of 8100 pounds a hover turn rate of 21.1 deg/sec was arrested with a peak load of 178 shp, and the time above 165 shp was 0.6 seconds. Following these tests, the examination of the gear boxes revealed a slight change in the gear wear pattern; but this change was not beyond the allowable tolerance. This was the final flight of the program; therefore, the wear included all which was experienced during 18 hours of testing. The results indicate that rapid arrestment of hover turn rates greater than 30 deg/sec produce very high power loads in the tail rotor drive system. Large pedal inputs (more than one inch) must be avoided, regardless of the initial turn rate, to prevent excessive power loading of the tail rotor shaft or at least to minimize the period of time the tail rotor shaft horsepower limit is exceeded. The operator's manual should be amended to include the warning note as worded in the safety of flight release (ref 6, app I).

CONCLUSIONS

31. The tractor tail rotor modification on the AH-1G helicopter improves the IGE maneuvering directional control and increases the payload capability significantly for similar wind/azimuth restrictions (para 28).

32. The tractor tail rotor modification does not solve the basic directional control problem of the AH-1G, and significant flight and gross weight restrictions are still required (para 28).

33. The change to the yaw control geometry included in the tractor tail rotor modification is essential for all AH-1G helicopters and should be incorporated at the earliest possible time (para 25).

34. A clear design and performance criteria for IGE yaw control power and directional response required for land based, attack helicopters should be developed for future designs and current engineering test evaluations (para 23).

35. The power loads in the tail rotor drive system with the tractor configuration are near the maximum allowed for stabilized IGE flight near the envelope limits and exceed the maximum allowed during IGE maneuvers requiring left pedal inputs (para 30).

36. The level flight and hover performance results for the tractor tail rotor AH-1G are close to those for the standard AH-1G. The exact amount and significance of the difference would require further testing with a calibrated engine installed (paras 12 and 13).

37. The handling qualities of the tractor tail rotor configuration throughout the forward flight envelope are the same as those for the standard AH-1G (paras 14 through 23).

RECOMMENDATION

38. It is recommended that:

a. The tractor tail rotor modification be considered for operational AH-1G helicopters as an interim solution for the directional control problem.

b. An immediate study and/or development program be initiated to provide a directional control system which will eliminate present wind/azimuth and gross weight restrictions and accept the resulting power loads without gear box damage.

c. A design performance criteria for land based, attack helicopter directional control power and response requirements be established.

APPENDIX I. REFERENCES

1. Test Plan, USAAVNTA Project No. 68-37, "Engineering Flight Test of the AH-1G Helicopter Equipped with a Tractor Tail Rotor, Army Preliminary Evaluation," September 1968.

2. Final Report, USAAVNTA Project No. 66-06, "Engineering Flight Test of the AH-1G Helicopter, Phase B, Part 1," January 1968.

3. Final Report, USAAVNTA Project No. 66-06, "Engineering Flight Test of the AH-1G Helicopter to Determine the Area of Inadequate Directional Control Power at 8100 Pounds Gross Weight," February 1968.

4. Final Report, USAAVNTA Project No. 66-06, "Feasibility Test of Tractor Tail Rotor Modification on the AH-1G Helicopter," March 1968.

5. Engineering Change Proposal AH-1G 350, Bell Helicopter Company, "Improved Anti-Torque System for the AH-1G Helicopter," 29 August 1967.

6. Unclassified Message, AMSAV-EF 8-1328, SUBJECT: "Safety of Flight Release for Tractor Tail Rotor Configuration, AH-1G," 8 August 1968.

7. Test Directive, USAAVCOM Project No. 68-37, "AH-1G Tractor Tail Rotor, Army Preliminary Evaluation," 19 July 1968.

8. Operator's Manual Army Model AH-1G Helicopter, TM55-1520-221-10, April 1967.

APPENDIX II. TEST DATA

FIGURE NO. 1
HOVER PERFORMANCE
AH-1G USA S/N 66-15283
TETHERED METHOD
TRACTOR TAIL ROTOR
WINDS LESS THAN THREE KNOTS
AVG. DENSITY ALTITUDE ~5545 FT.
C.G. STATION ~195.0 IN.
CONFIGURATION ~CLEAN

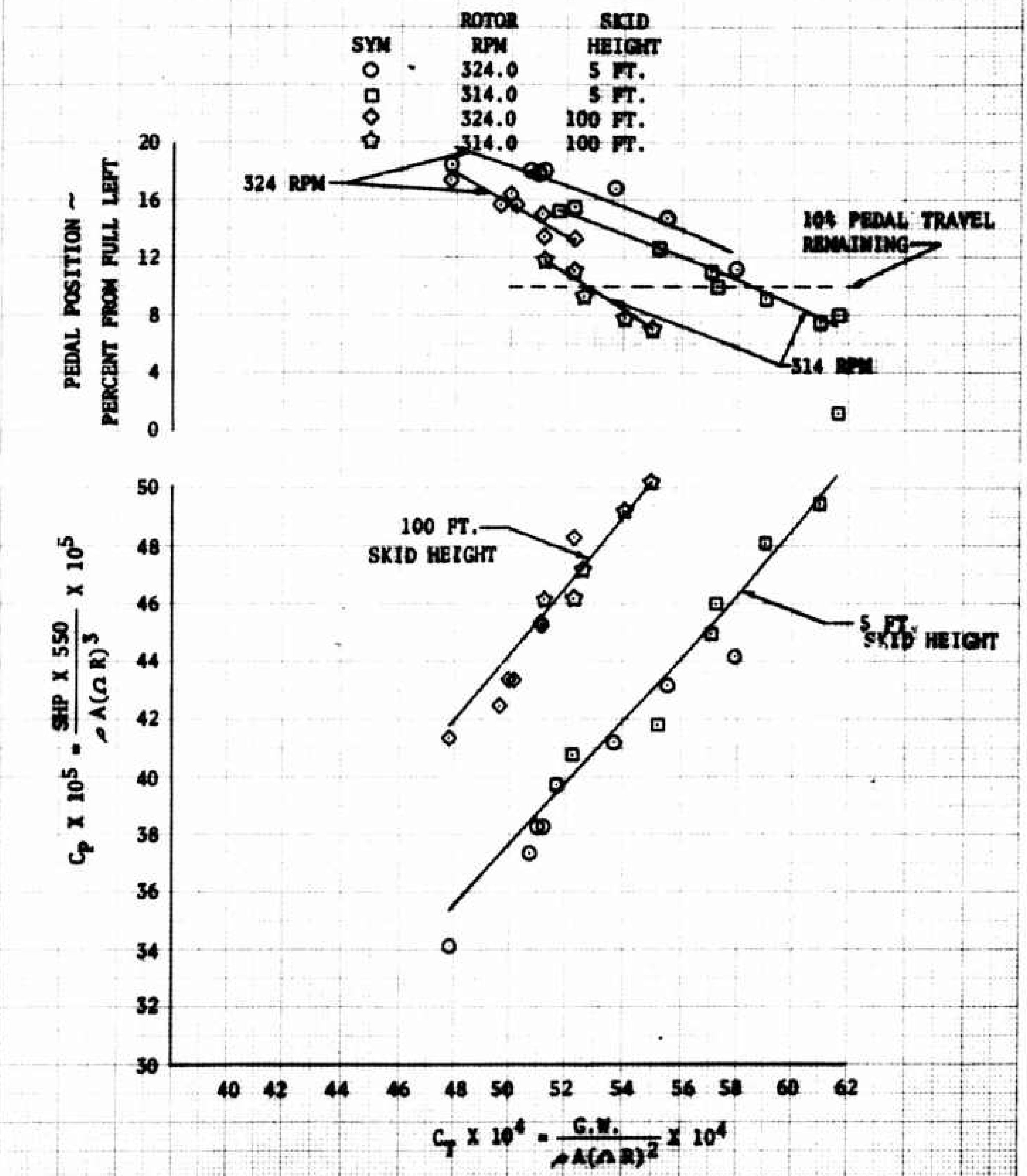


FIGURE NO. 2

LEVEL FLIGHT PERFORMANCE
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR

AVG. GROSS WEIGHT	~	8070 LBS.
AVG. DENSITY ALTITUDE	~	5220 FT.
AVG. C.G. STATION	~	190.4 IN.
ROTOR SPEED	~	324 RPM
CONFIGURATION	~	HOG
C_T	~	46.83×10^{-4}

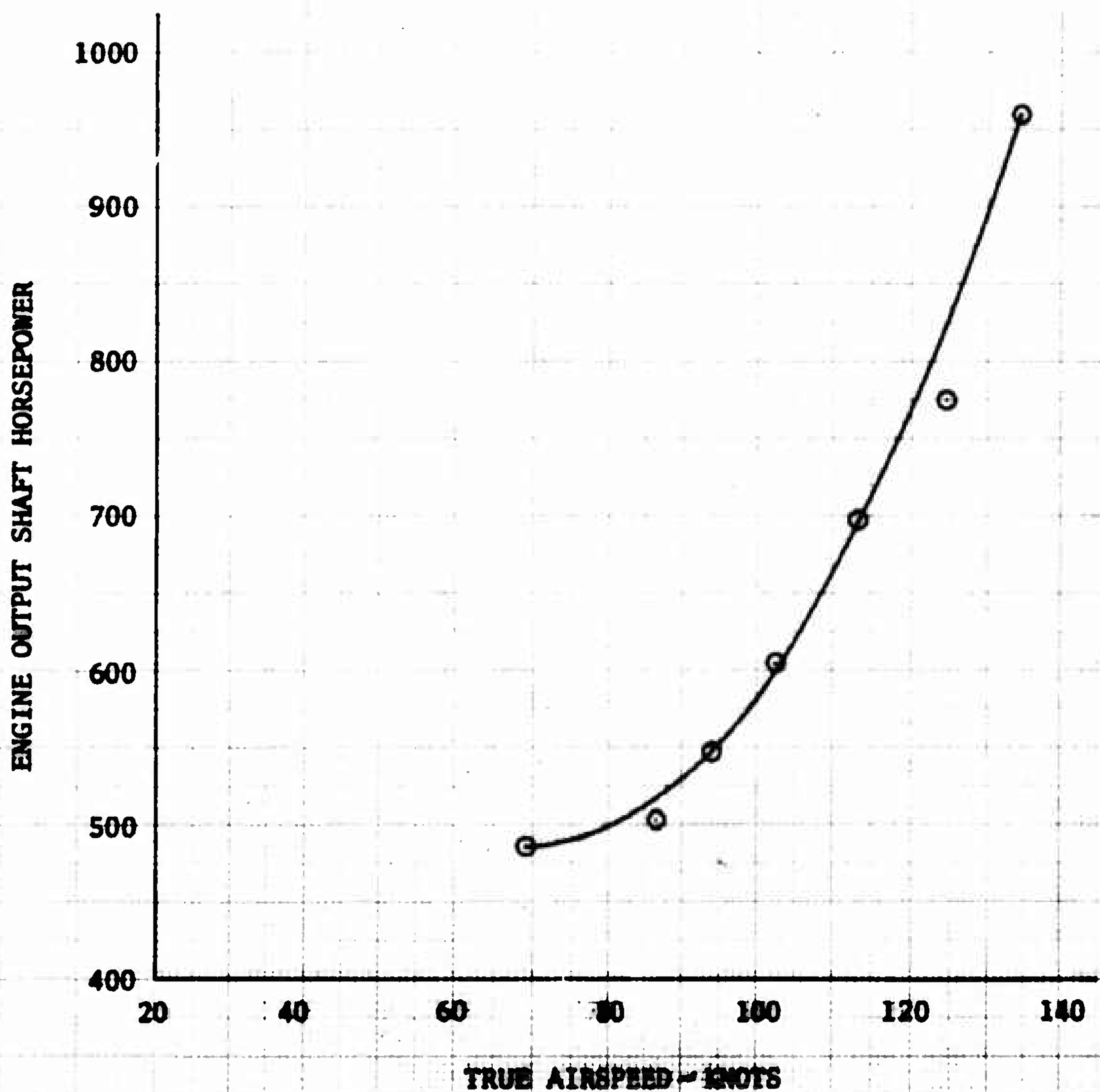


FIGURE NO. 3

LEVEL FLIGHT PERFORMANCE
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR

AVG. GROSS WEIGHT	~	8315 LBS.
AVG. DENSITY ALTITUDE	~	5365 FT.
AVG. C.G. STATION	~	191.0 IN.
ROTOR SPEED	~	324 RPM
CONFIGURATION	~	HOG
C_T	~	48.48×10^{-4}

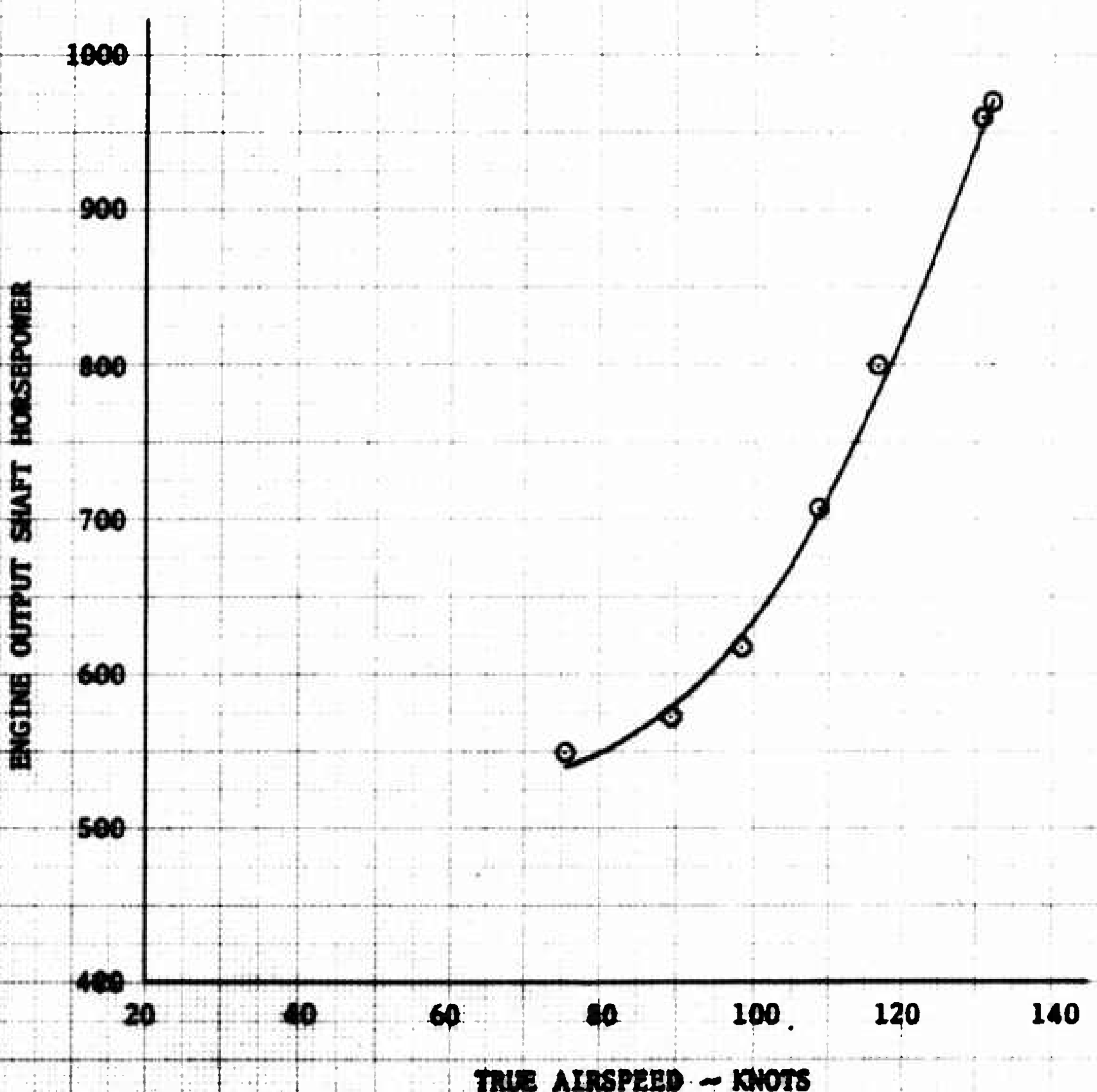


FIGURE NO. 4

LEVEL FLIGHT PERFORMANCE
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR

AVG. GROSS WEIGHT	~	8440 LBS.
AVG. DENSITY ALTITUDE	~	10,180 FT.
AVG. C.G. STATION	~	191.2 IN.
ROTOR SPEED	~	324 RPM
CONFIGURATION	~	HOG
C_T	~	57.10×10^{-4}

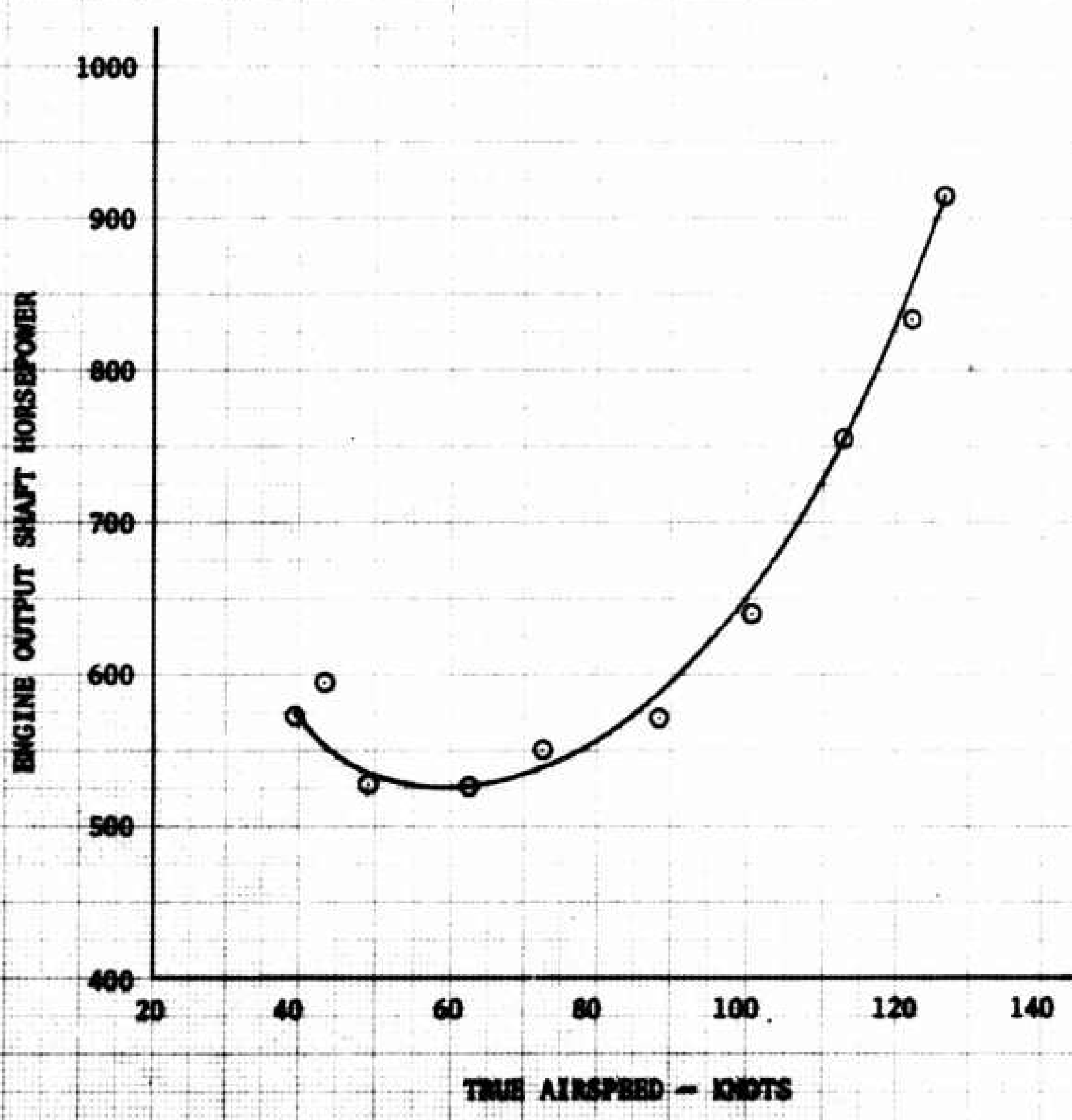


FIGURE NO. 5

HOVER PERFORMANCE
AH-1G USA S/N 66-15283
TETHERED METHOD
TRACTOR TAIL ROTOR

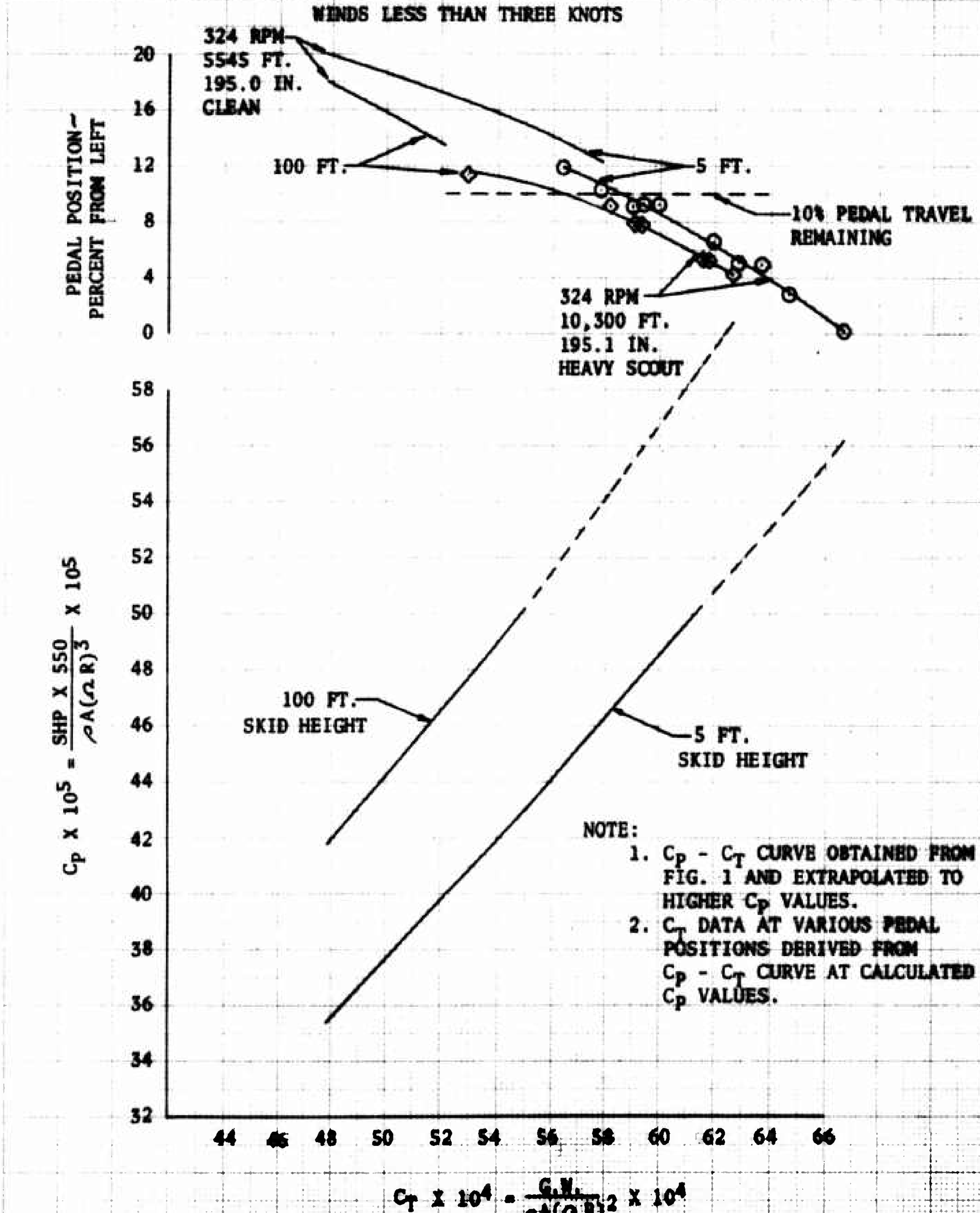


FIGURE NO 6
CONTROL TRIM POSITION DURING LEVEL FLIGHT
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR

SYM	AVG GROSS WEIGHT LBS	AVG C.G. STATION IN	DENSITY ALTITUDE FT	ROTOR SPEED RPM	CONFIG
▽	8070	191.0	5220	324	HOG
◇	8315	191.0	5365	324	HOG
○	8440	191.2	10,180	324	HOG

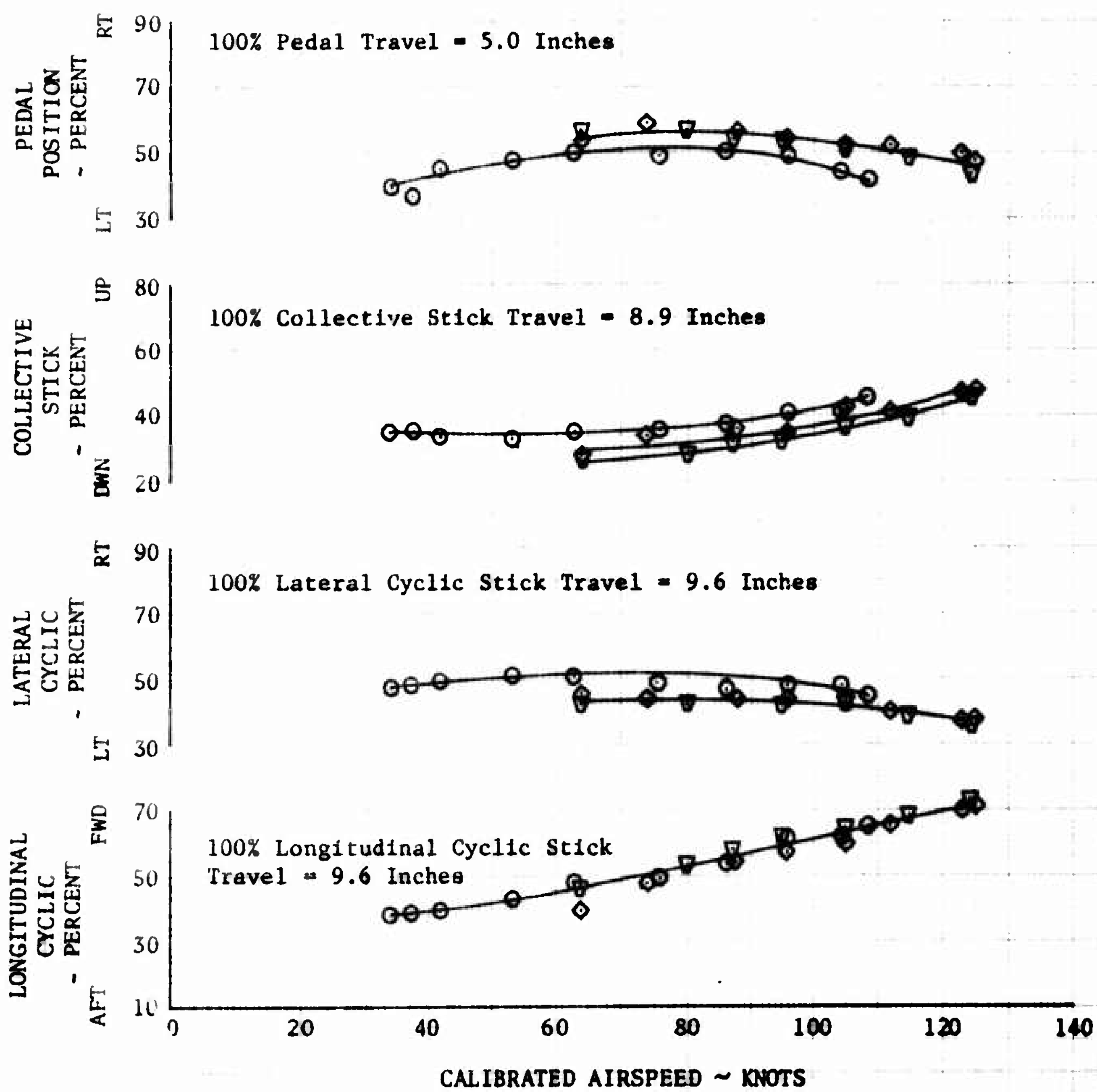


FIGURE NO 7
STATIC LATERAL DIRECTIONAL STABILITY
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR

SYM	TRIM AIRSPEED KCAS	AVG GROSS WEIGHT LBS	AVG C.G. STATION IN	DENSITY ALTITUDE FT	ROTOR SPEED RPM	CONFIG
○	106	8400	192.2	6300	324	CLEAN
◇	125	8315	192.2	6200	324	CLEAN
□	137	8220	192.0	6200	324	CLEAN

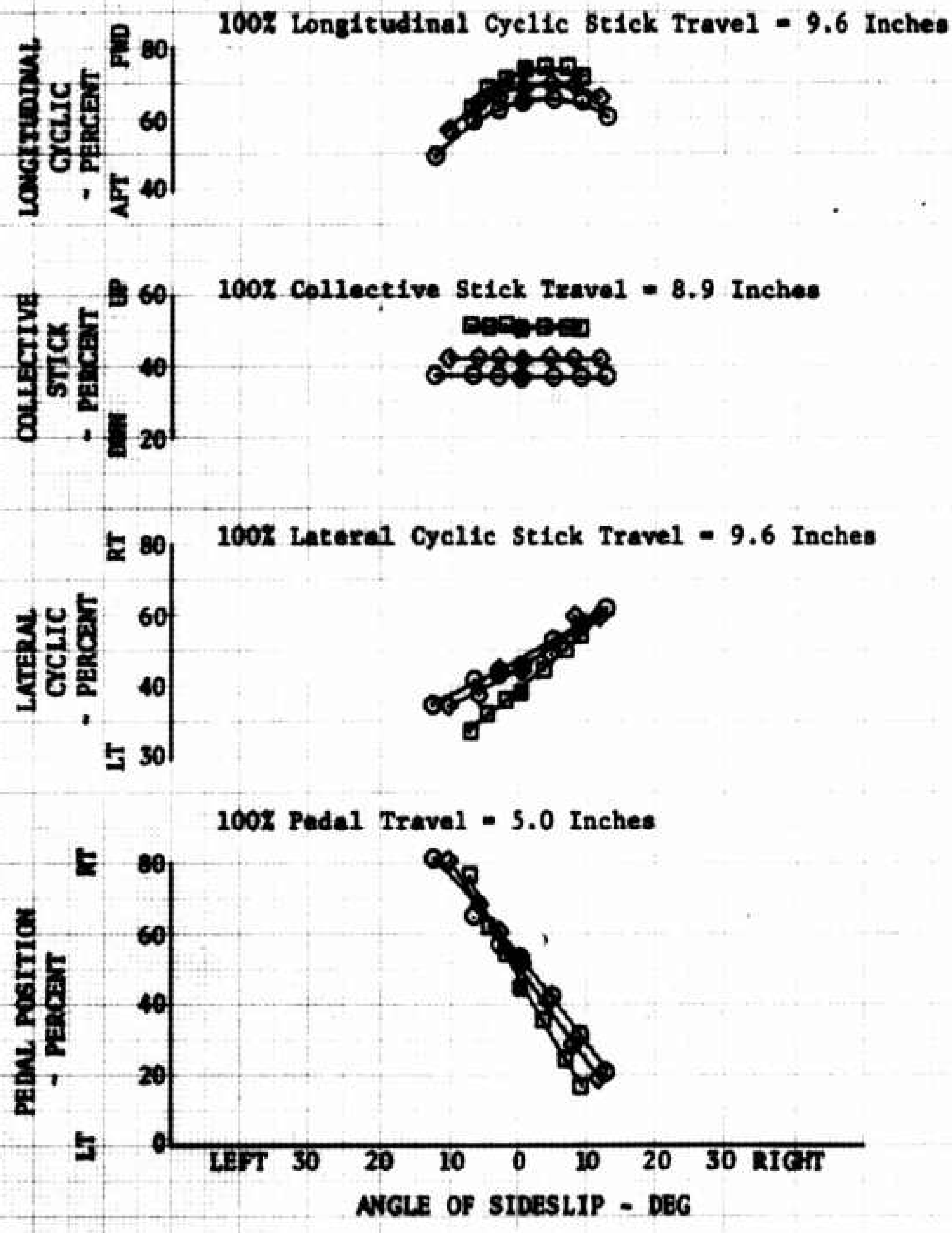


FIGURE NO 8
LATERAL RESPONSE
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR
SCAS ON

SYM	AVG GROSS WT	AVG C.G. STATION	AVG DENSITY ALT	ROTOR SPEED	CONFIG
O	8025 LBS	197.5 IN	4200 FT	324 RPM	CLEAN
Δ	8805 LBS	192.5 IN	5660 FT	324 RPM	CLEAN
□	7280 LBS	194.5 IN	10,660 FT	324 RPM	CLEAN

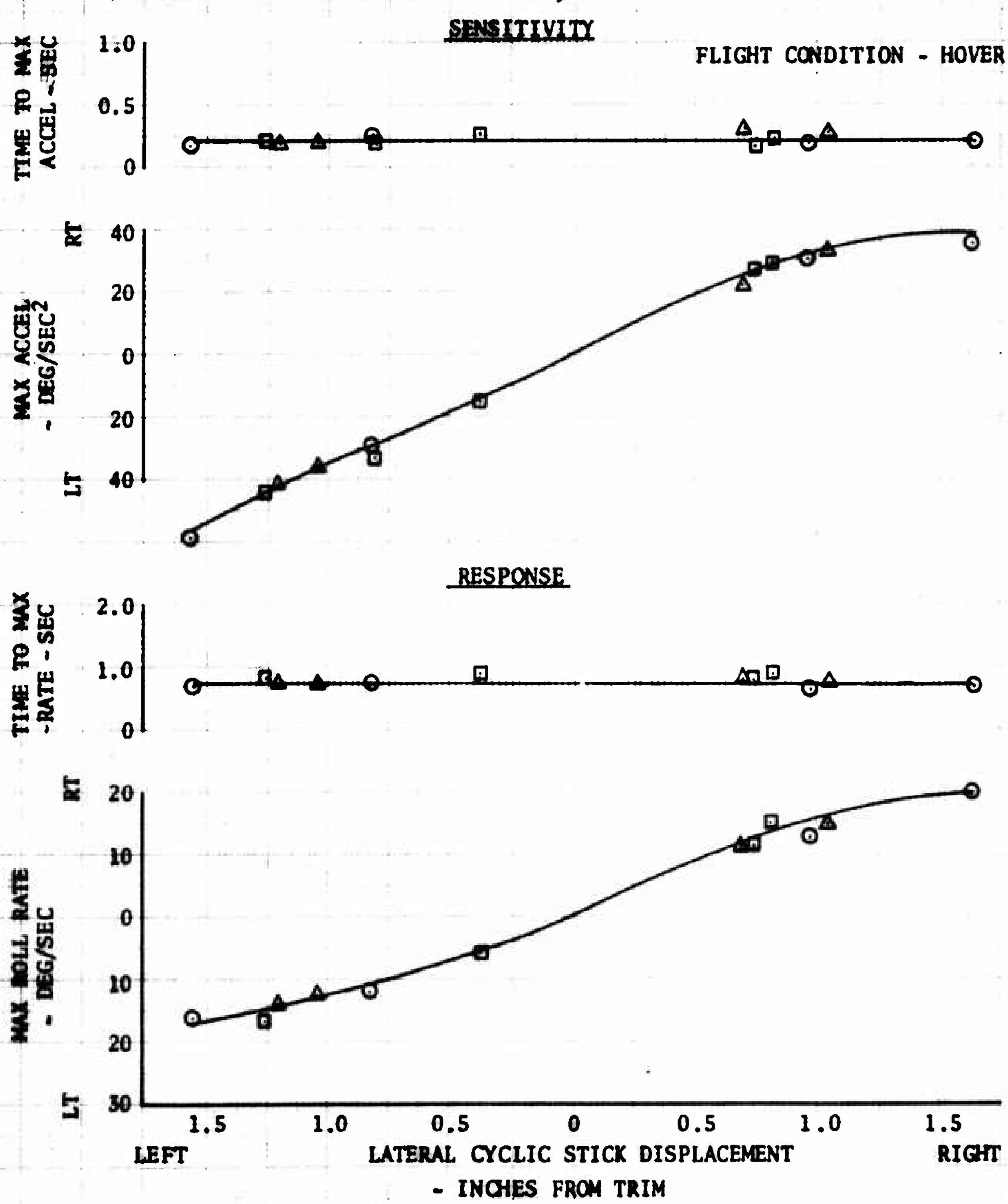


FIGURE NO 9
LATERAL RESPONSE
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR
SCAS OFF

SYM	AVG GROSS WT	AVG C.G. STATION	AVG DENSITY ALT	ROTOR SPEED	CONFIG
○	7920 LBS	197.6 IN	4200 FT	324 RPM	CLEAN
△	8805 LBS	192.5 IN	5660 FT	324 RPM	CLEAN
□	7280 LBS	194.5 IN	10,660 FT	324 RPM	CLEAN

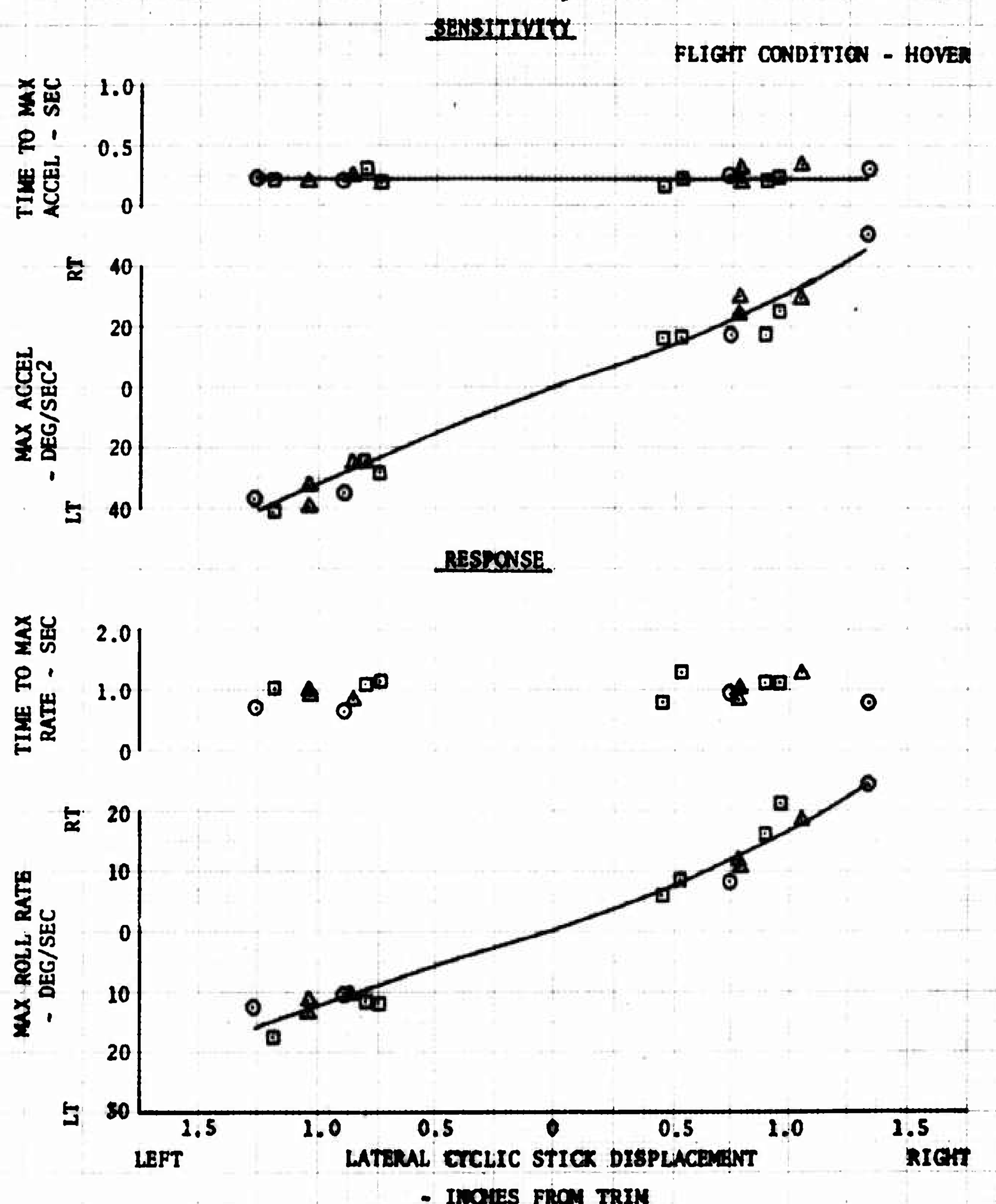


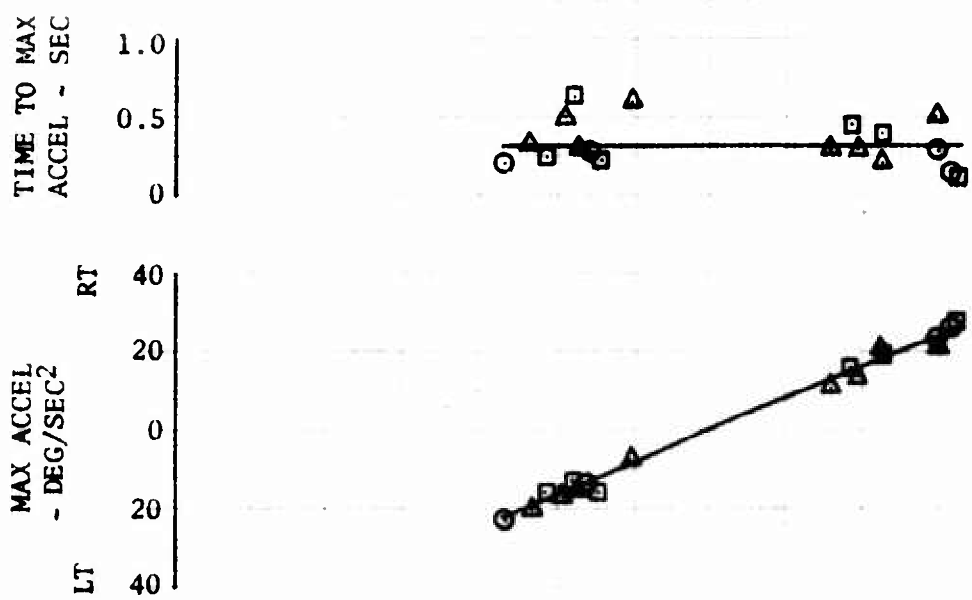
FIGURE NO 10
DIRECTIONAL RESPONSE
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR
SCAS ON

SYM	AVG GROSS WT	AVG C.G. STATION	AVG DENSITY ALT	ROTOR SPEED	CONFIG
○	8000 LBS	197.4 IN	4200 FT	324 RPM	CLEAN
△	8680 LBS	193.5 IN	5660 FT	324 RPM	CLEAN
□	7375 LBS	195.0 IN	10,660 FT	324 RPM	CLEAN
*⬯	7490 LBS	195.9 IN	10,550 FT	324 RPM	CLEAN
*△	8170 LBS	195.2 IN	4120 FT	324 RPM	CLEAN
*◇	7370 LBS	194.8 IN	5040 FT	324 RPM	CLEAN

* Implies standard tail rotor configuration

SENSITIVITY

FLIGHT CONDITION - HOVER



YAW RATE MEASURED AT ONE SEC

RESPONSE

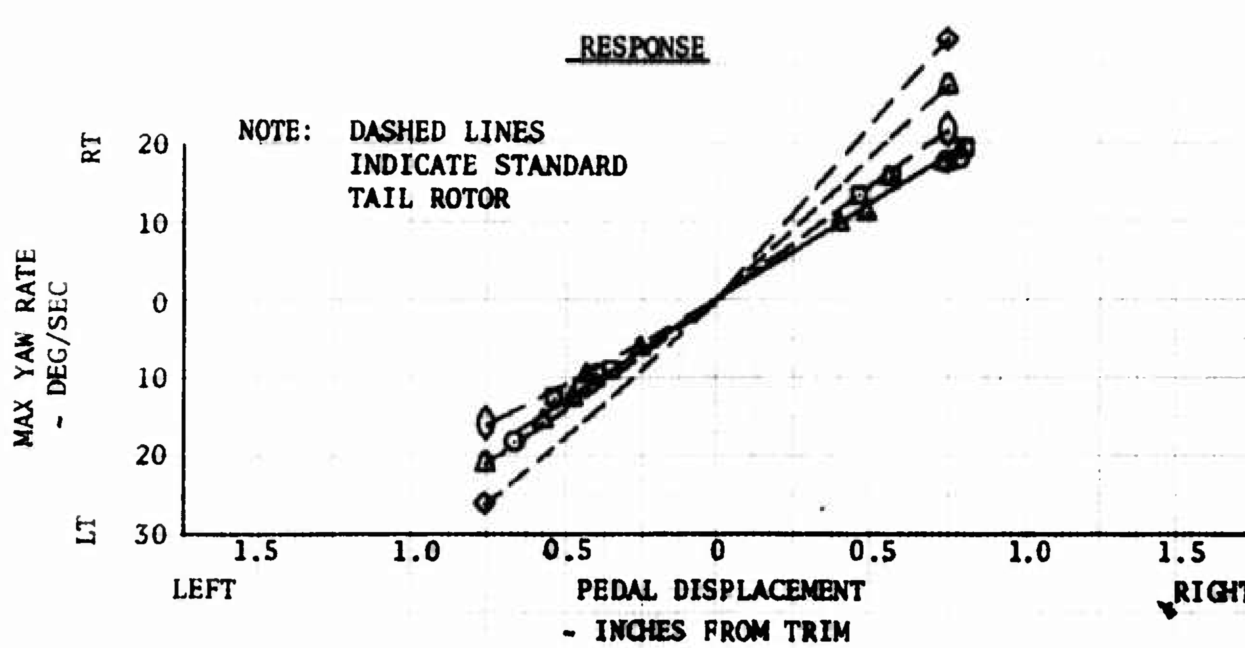


FIGURE NO 11
DIRECTIONAL RESPONSE
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR
SCAS OFF

SYM	AVG GROSS WT	AVG C.G. STATION	AVG DENSITY ALT.	ROTOR SPEED	CONFIG
○	8000 LBS	197.4 IN	4200 FT	324 RPM	CLEAN
△	8680 LBS	195.5 IN	5660 FT	324 RPM	CLEAN
□	7375 LBS	195.0 IN	10,660 FT	324 RPM	CLEAN
*○	7370 LBS	194.8 IN	5040 FT	324 RPM	CLEAN
*◇	8170 LBS	195.2 IN	4120 FT	324 RPM	CLEAN

* Implies standard tail rotor configuration

SENSITIVITY

FLIGHT CONDITION - HOVER

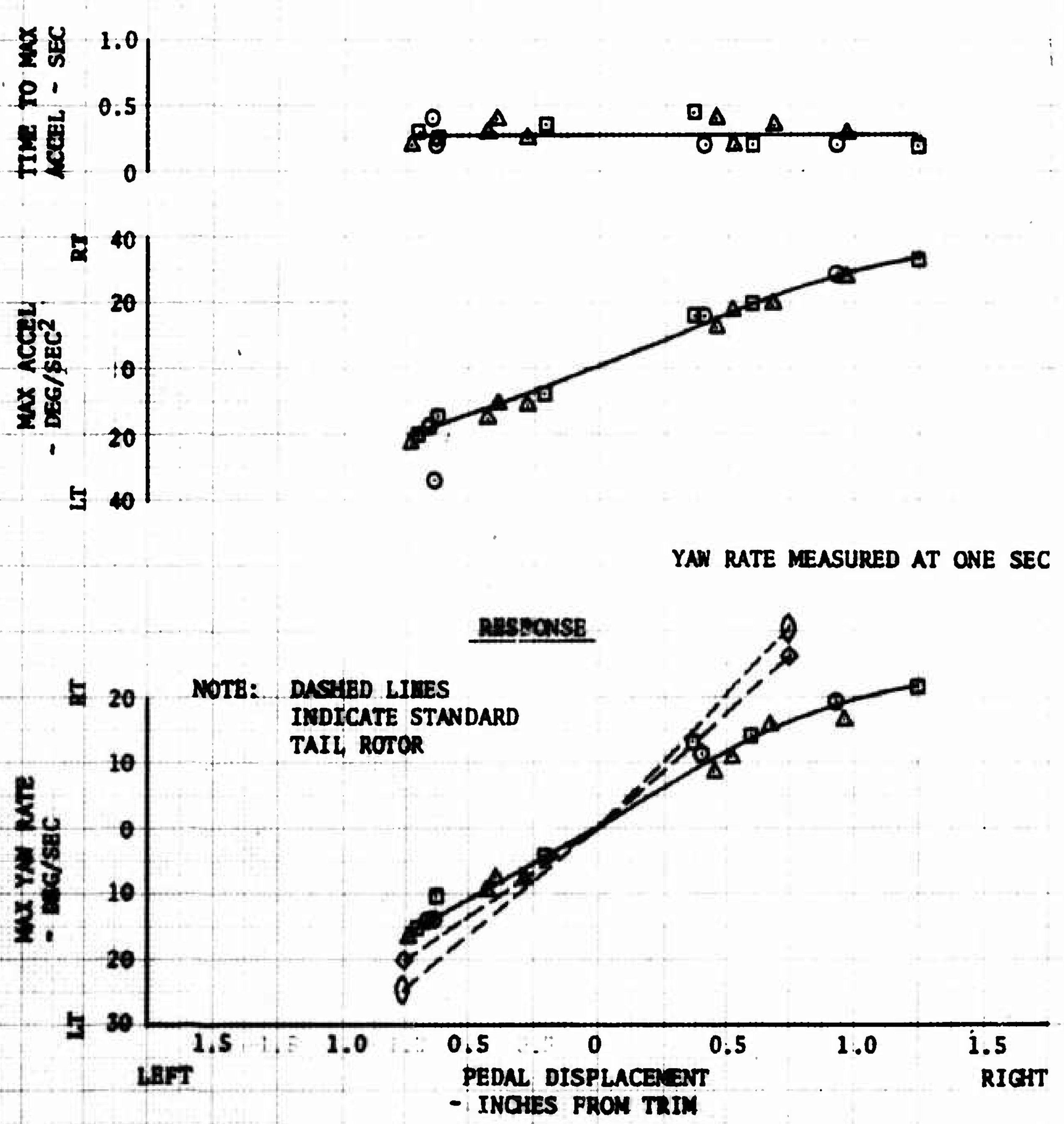


FIGURE NO 12
LATERAL RESPONSE
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR
SCAS ON

SYM	AVG GROSS WT	AVG C.G. STATION	AVG DENSITY ALT	ROTOR SPEED	CONFIG
○	8030 LBS	200.0 IN	5220 FT	324 RPM	HOG
△	7705 LBS	200.0 IN	5370 FT	324 RPM	HOG

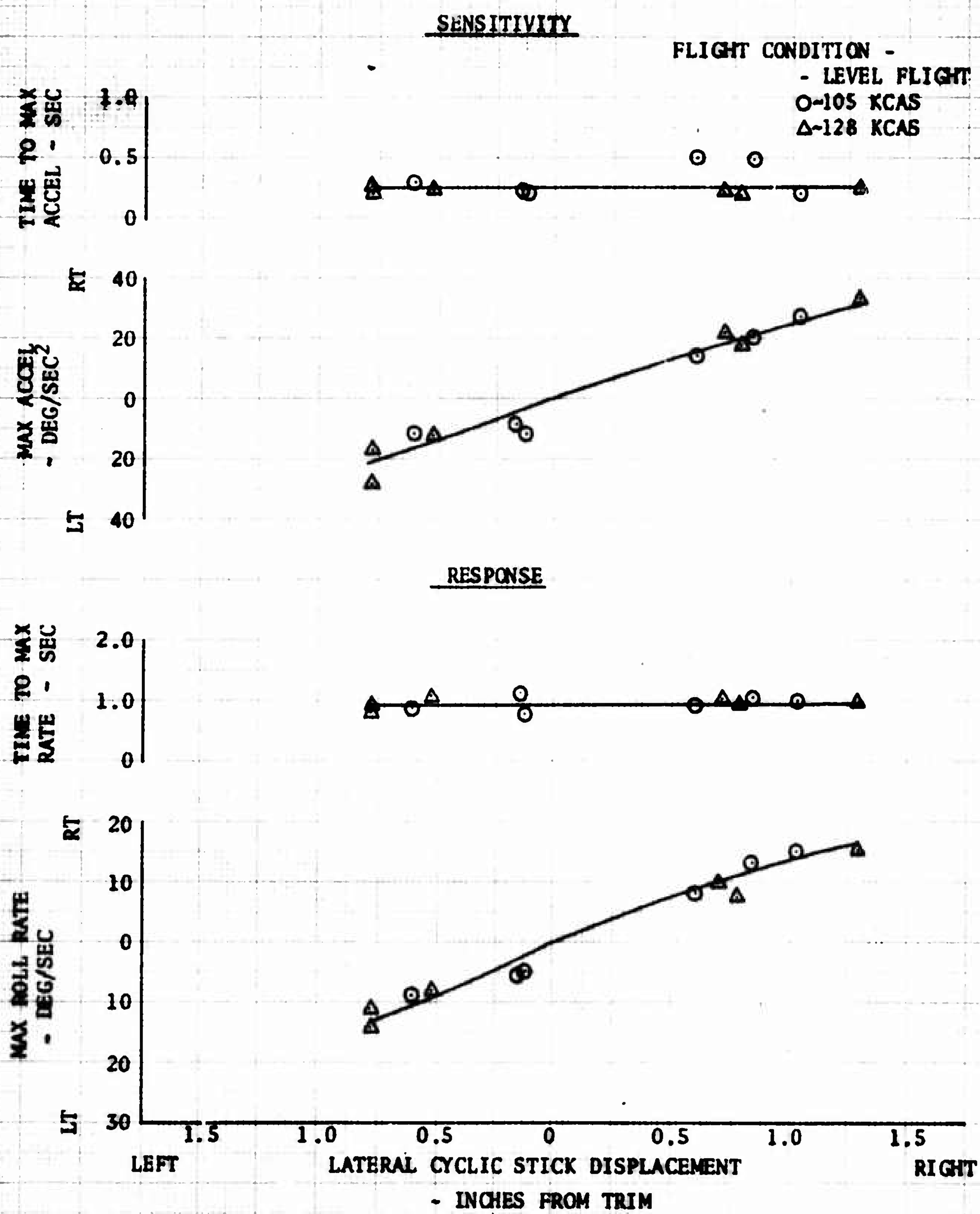


FIGURE NO 13
LATERAL RESPONSE
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR
SCAS OFF

SYM	AVG GROSS WT	AVG C.G. STATION	AVG DENSITY ALT	ROTOR SPEED	CONFIG
O	8030 LBS	200.0 IN	5220 FT	324 RPM	HOG
Δ	7705 LBS	200.0 IN	5370 FT	324 RPM	HOG

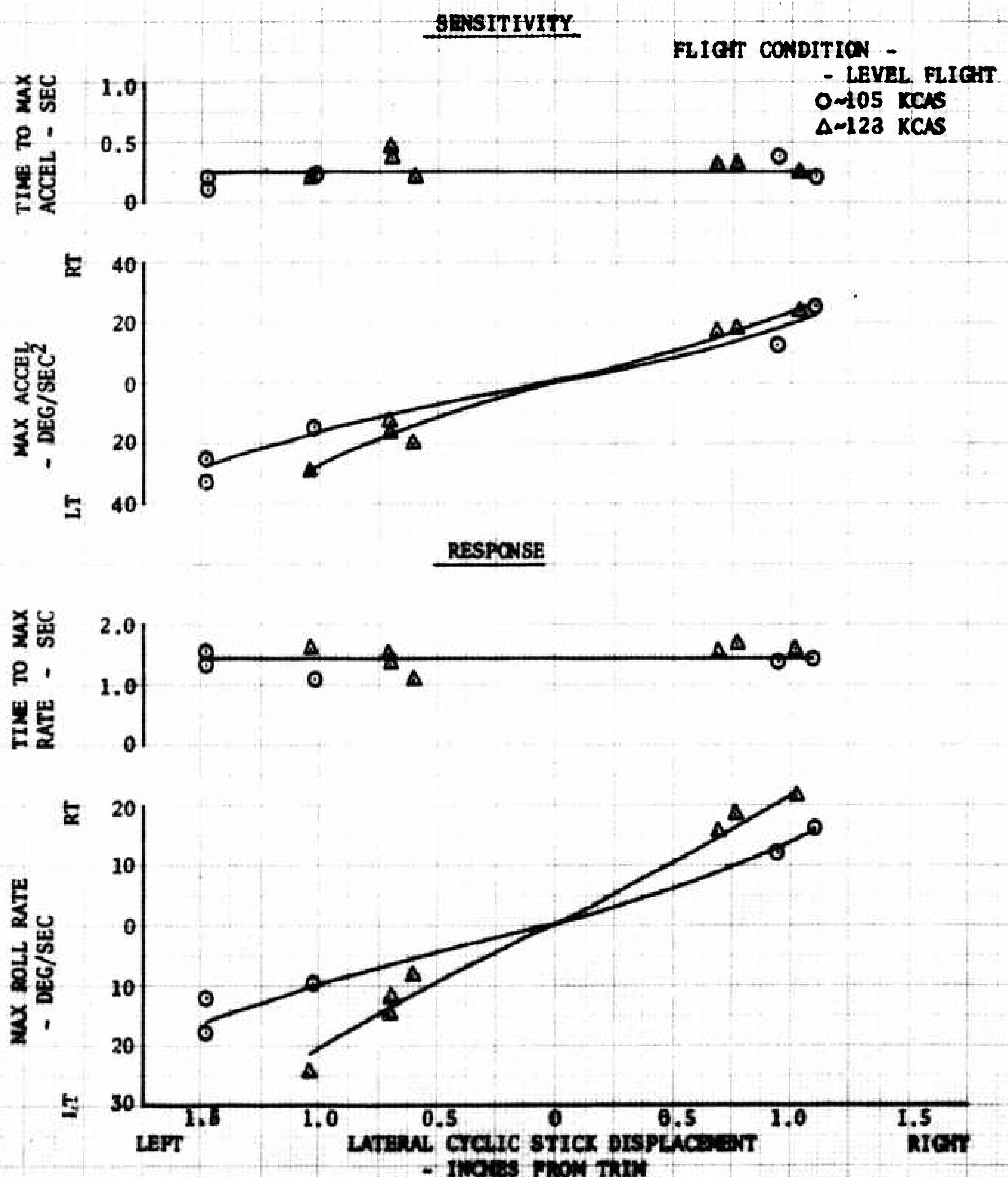


FIGURE NO 14
DIRECTIONAL RESPONSE
AH-1G USA S/N 66-15285
TRACTOR TAIL ROTOR
SCAS ON

SYM	AVG GROSS WT	AVG C.G. STATION	AVG DENSITY ALT	ROTOR SPEED	CONFIG
○	7880 LBS	200.0 IN	5220 FT	324 RPM	HOG
△	7805 LBS	200.0 IN	5370 FT	324 RPM	HOG

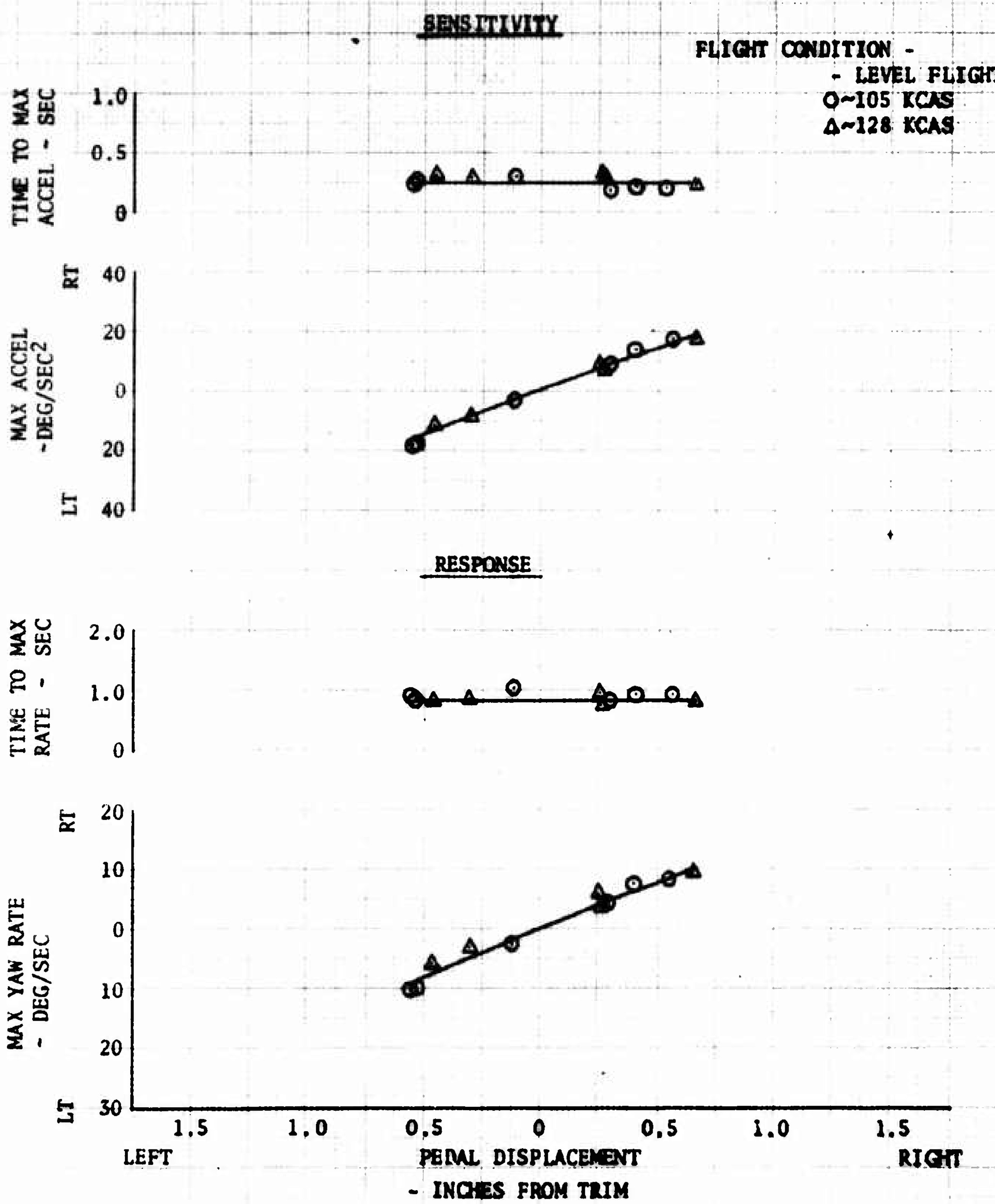


FIGURE NO 15
DIRECTIONAL RESPONSE
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR
SCAS OFF

SYM	AVG GROSS WT	AVG C.G. STATION	AVG DENSITY ALT	ROTOR SPEED	CONFIG
O	7880 LBS	200.0 IN	5220 FT	324 RPM	HOG
Δ	7805 LBS	200.0 IN	5370 FT	324 RPM	HOG

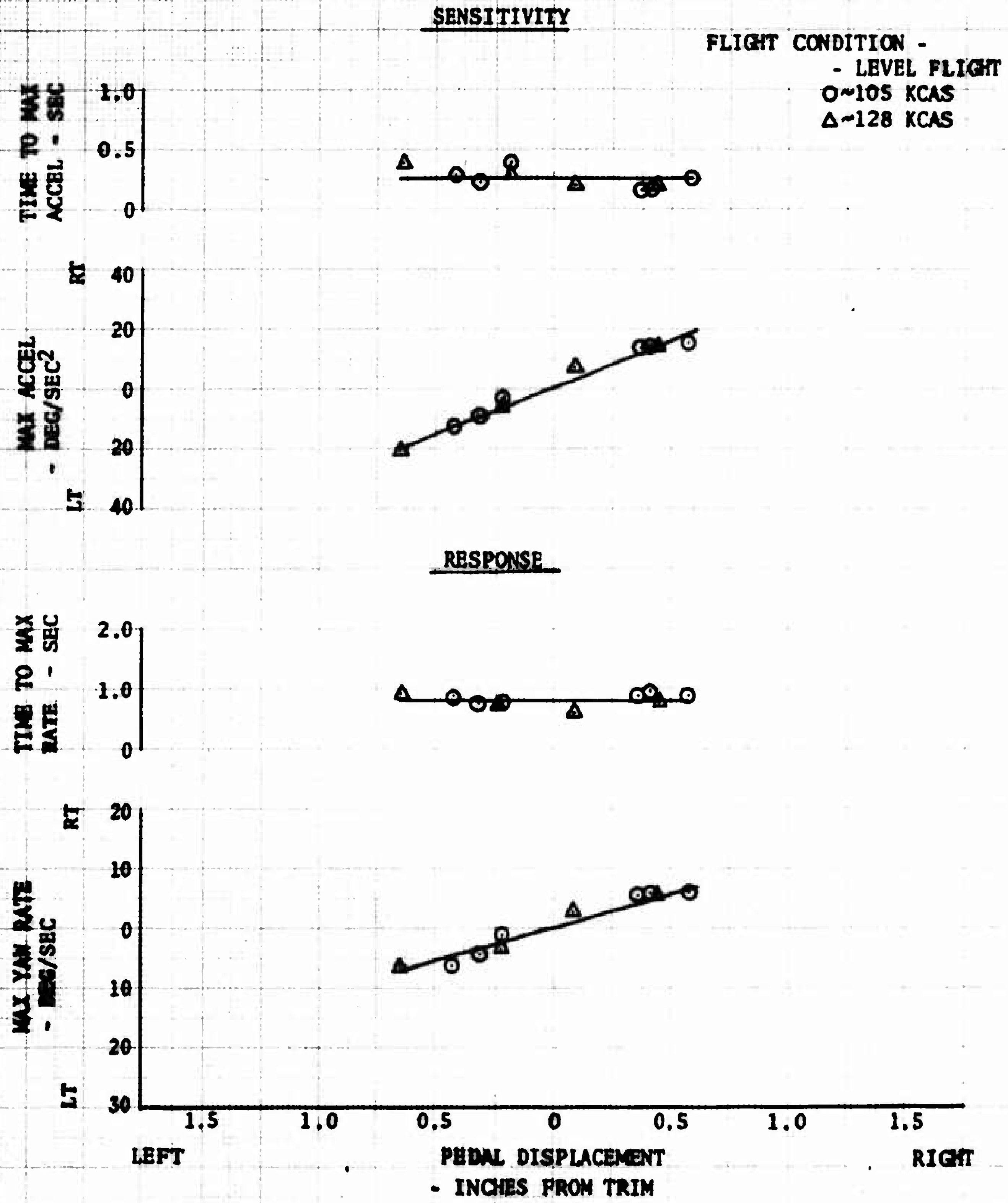


FIGURE NO 16
LATERAL RESPONSE
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR
SCAS ON

SYM	AVG GROSS WT	AVG C.G. STATION	AVG DENSITY ALT	ROTOR SPEED	CONFIG
△	8975 LBS	196.8 IN	6220 FT	324 RPM	HOG
○	8765 LBS	197.0 IN	6220 FT	324 RPM	HOG

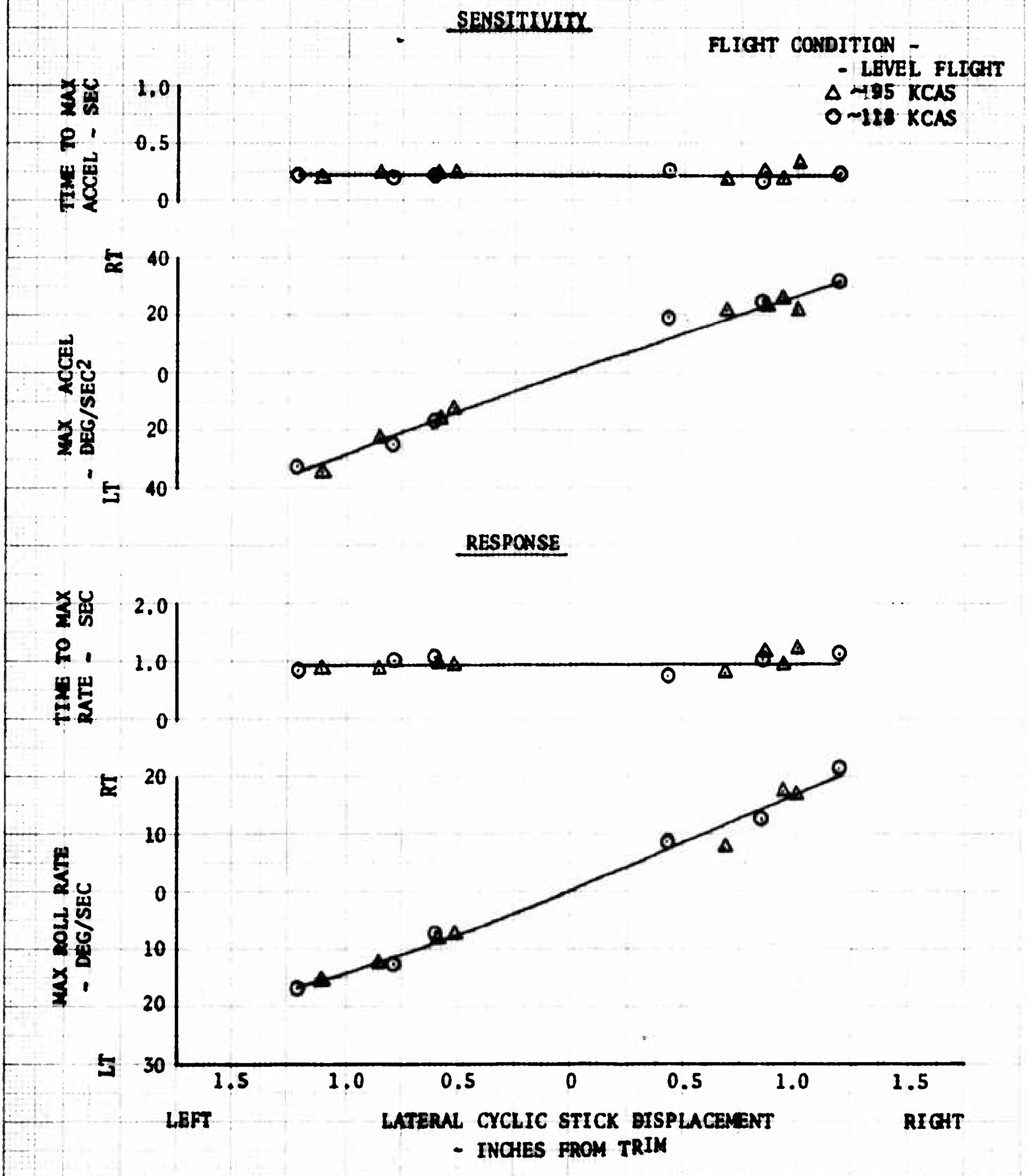


FIGURE NO 17
LATERAL RESPONSE
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR
SCAS OFF

SYM	AVG GROSS WT	AVG C.G. STATION	AVG DENSITY ALT	ROTOR SPEED	CONFIG
Δ	8975 LBS	196.8 IN	6220 FT	324 RPM	HOG
O	8765 LBS	197.0 IN	6220 FT	324 RPM	HOG

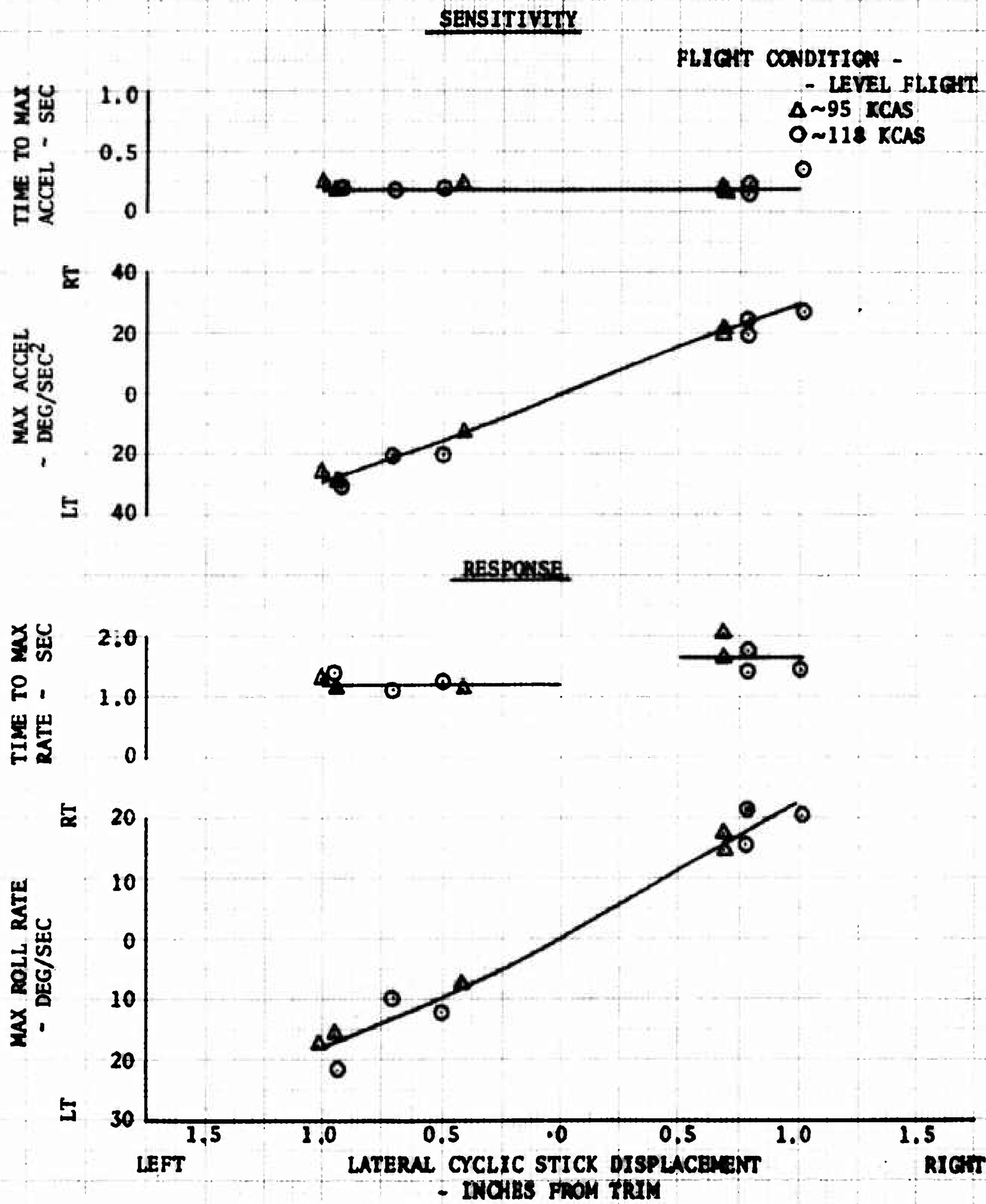


FIGURE NO 18
DIRECTIONAL RESPONSE
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR
SCAS ON

SYM	AVG GROSS WT	AVG C.G. STATION	AVG DENSITY ALT	ROTOR SPEED	CONFIG
△	9065 LB	196.8 IN	6120 FT	324 RPM	HOG
O	8875 LB	197.5 IN	6220 FT	324 RPM	HOG

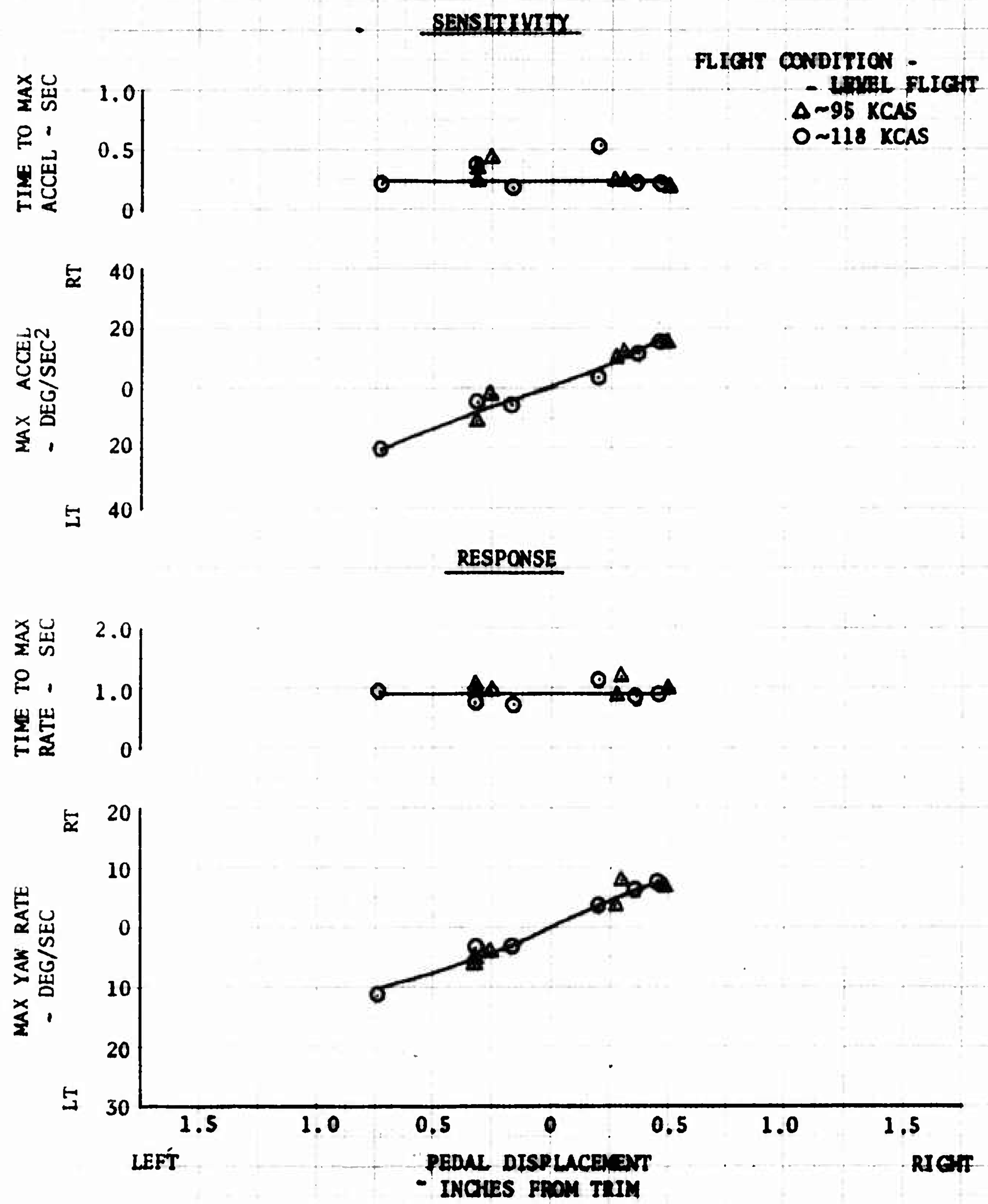
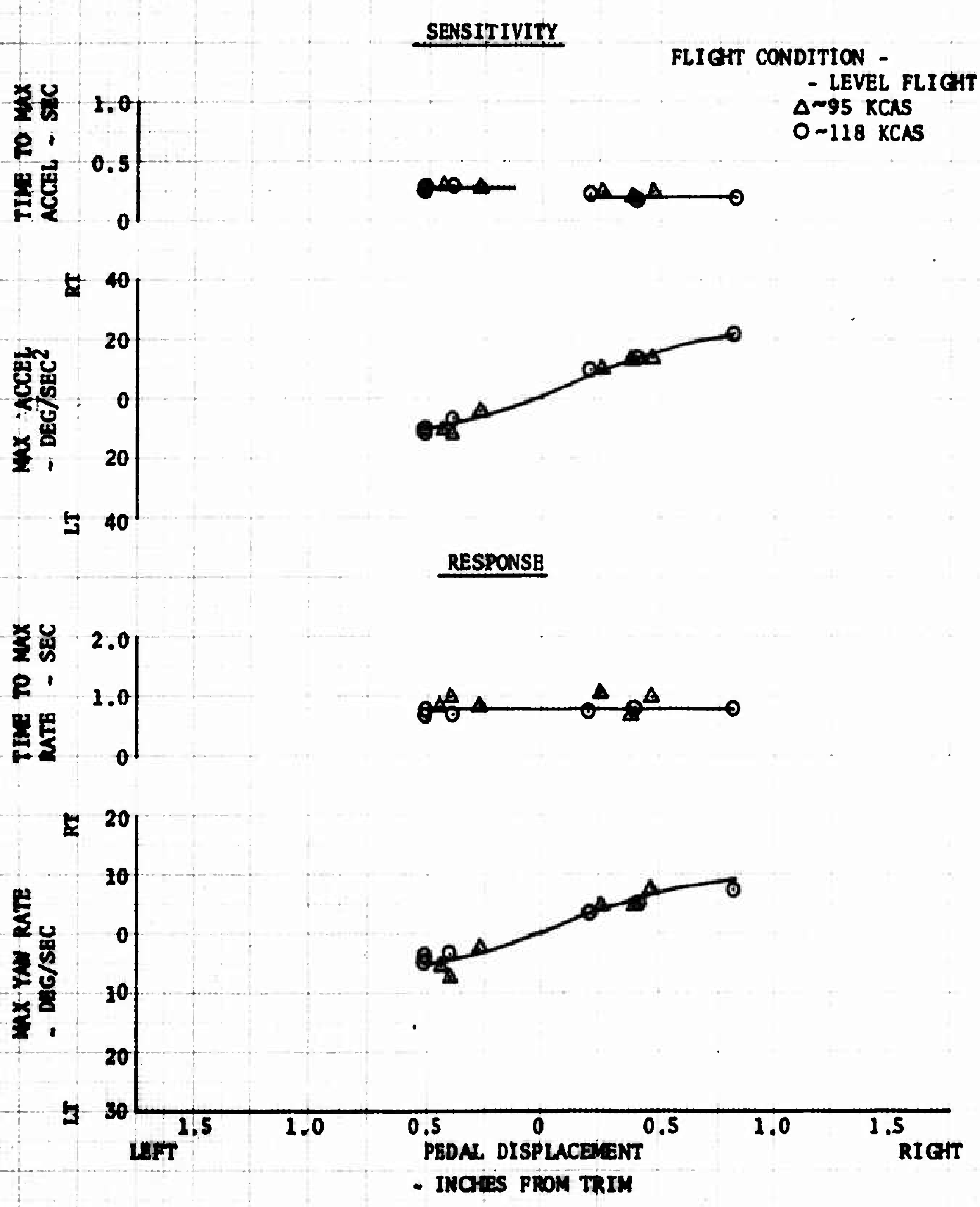


FIGURE NO 19
DIRECTIONAL RESPONSE
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR
SCAS OFF

SYM	AVG GROSS WT	AVG C.G. STATION	AVG DENSITY ALT	ROTOR SPEED	CONFIG
△	9065 LB	196.8 IN	6120 FT	324 RPM	HOG
○	8875 LB	197.5 IN	6220 FT	324 RPM	HOG



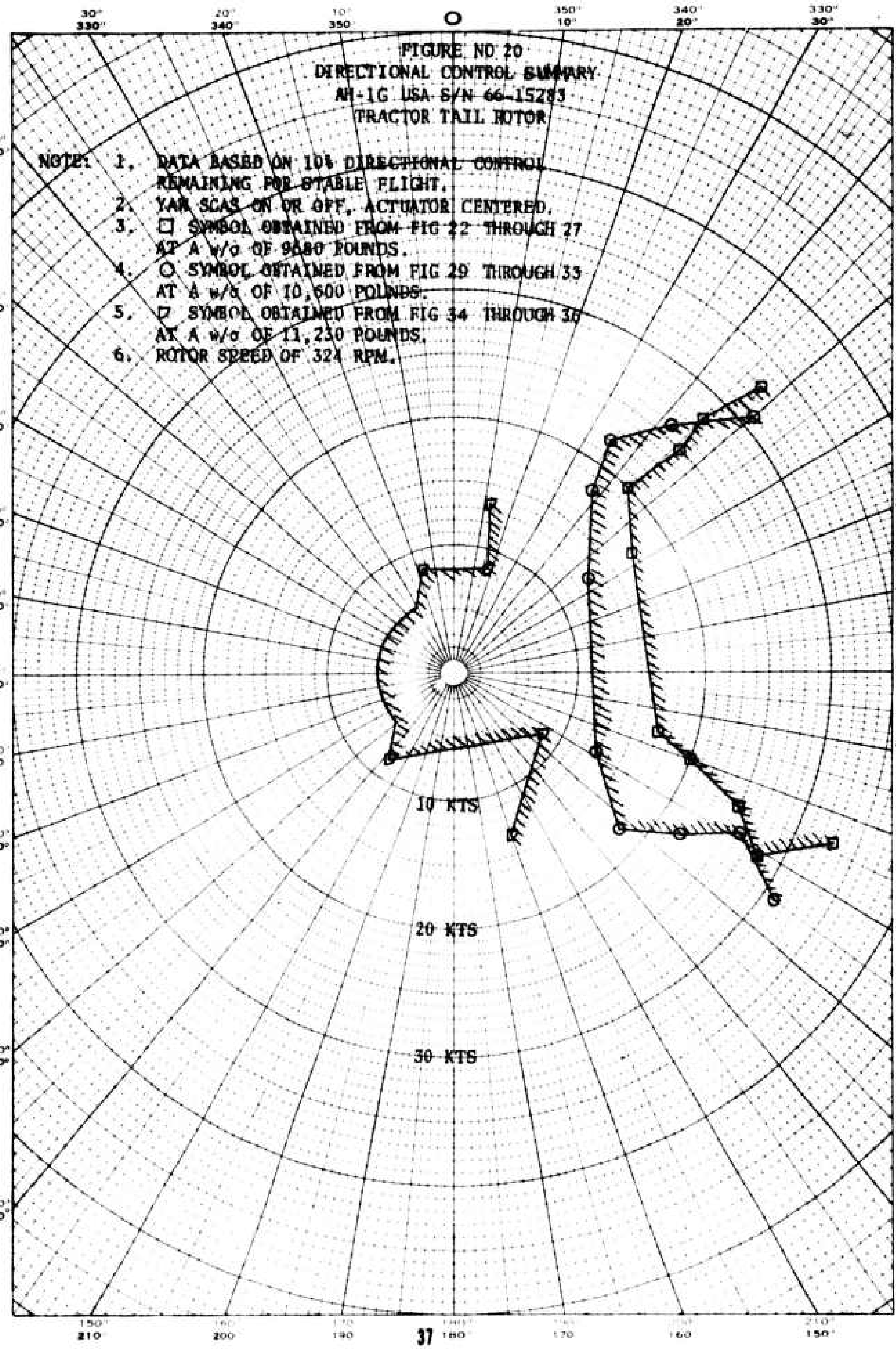


FIGURE NO 20
DIRECTIONAL CONTROL SUMMARY
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR
NOTE: 1. DATA BASED ON 10% DIRECTIONAL CONTROL REMAINING FOR STABLE FLIGHT.
2. YAW SCAS ON OR OFF, ACTUATOR CENTERED.
3. □ SYMBOL OBTAINED FROM FIG 22 THROUGH 27 AT A w/σ OF 9680 POUNDS.
4. ○ SYMBOL OBTAINED FROM FIG 29 THROUGH 33 AT A w/σ OF 10,600 POUNDS.
5. ◻ SYMBOL OBTAINED FROM FIG 34 THROUGH 36 AT A w/σ OF 11,230 POUNDS.
6. ROTOR SPEED OF 324 RPM.
10 KTS
20 KTS
30 KTS
0

FIGURE NO 21
DIRECTIONAL CONTROL AT VARIOUS RELATIVE WIND AZIMUTHS
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR

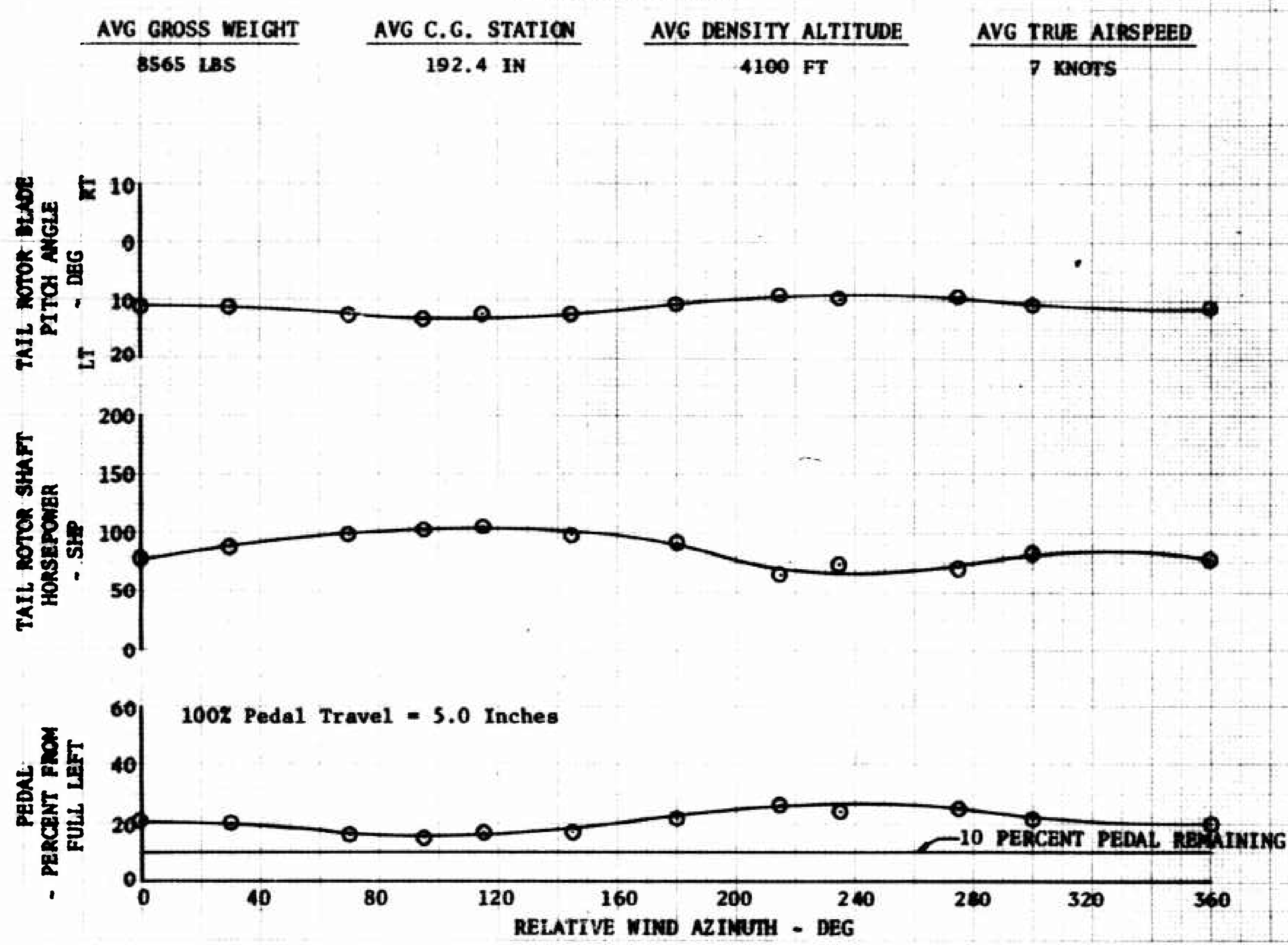


FIGURE NO 22
DIRECTIONAL CONTROL AT VARIOUS RELATIVE WIND AZIMUTHS
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR

AVG GROSS WEIGHT	AVG C.G. STATION	AVG DENSITY ALTITUDE	AVG TRUE AIRSPEED
8455 LBS	192.3 IN	4060 FT	12 KNOTS

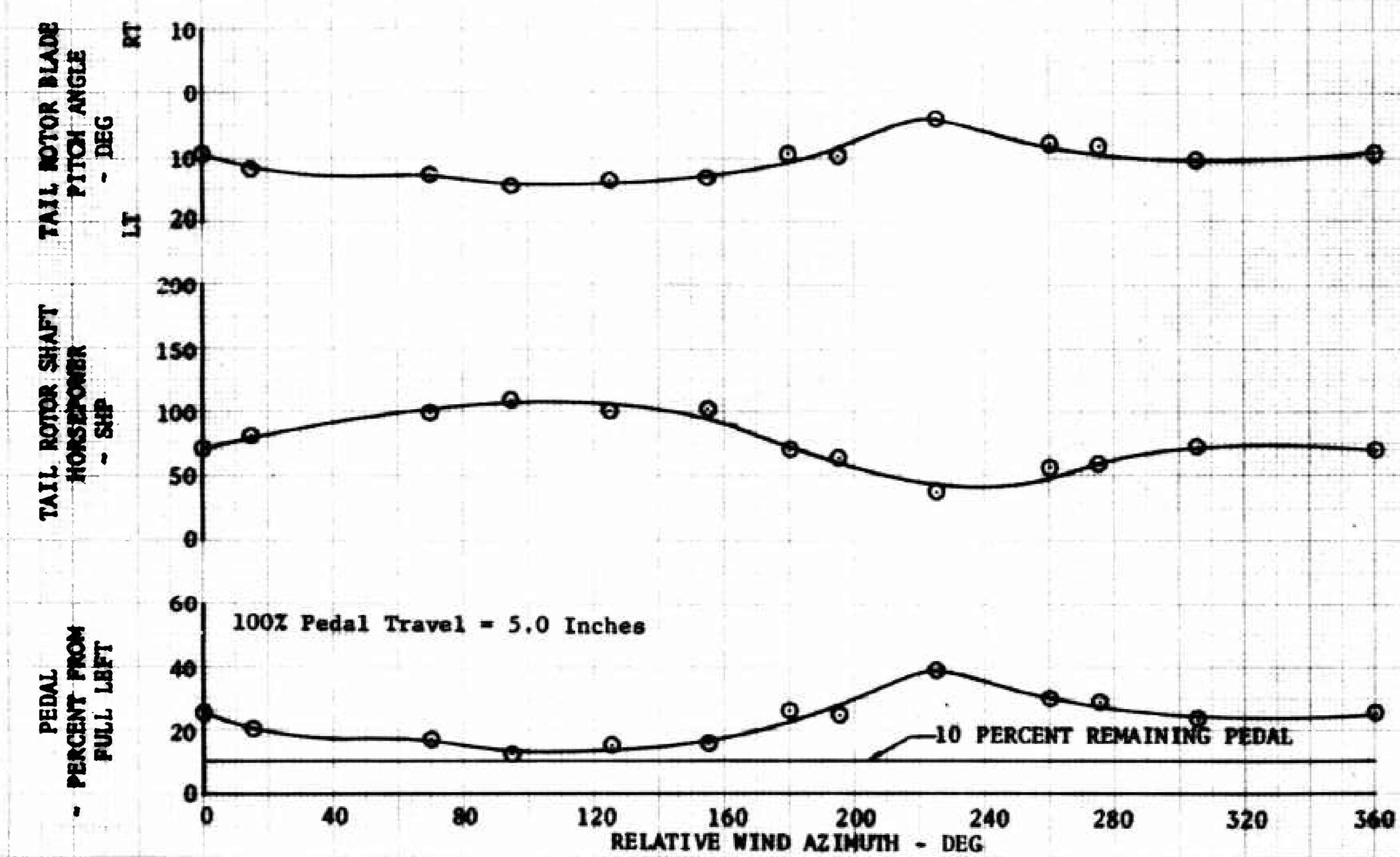


FIGURE NO 23
DIRECTIONAL CONTROL AT VARIOUS RELATIVE WIND AZIMUTHS
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR

AVG GROSS WEIGHT	AVG C.G. STATION	AVG DENSITY ALTITUDE	AVG TRUE AIRSPEED
8345 LBS	192.2 IN	4060 FT	17 KNOTS

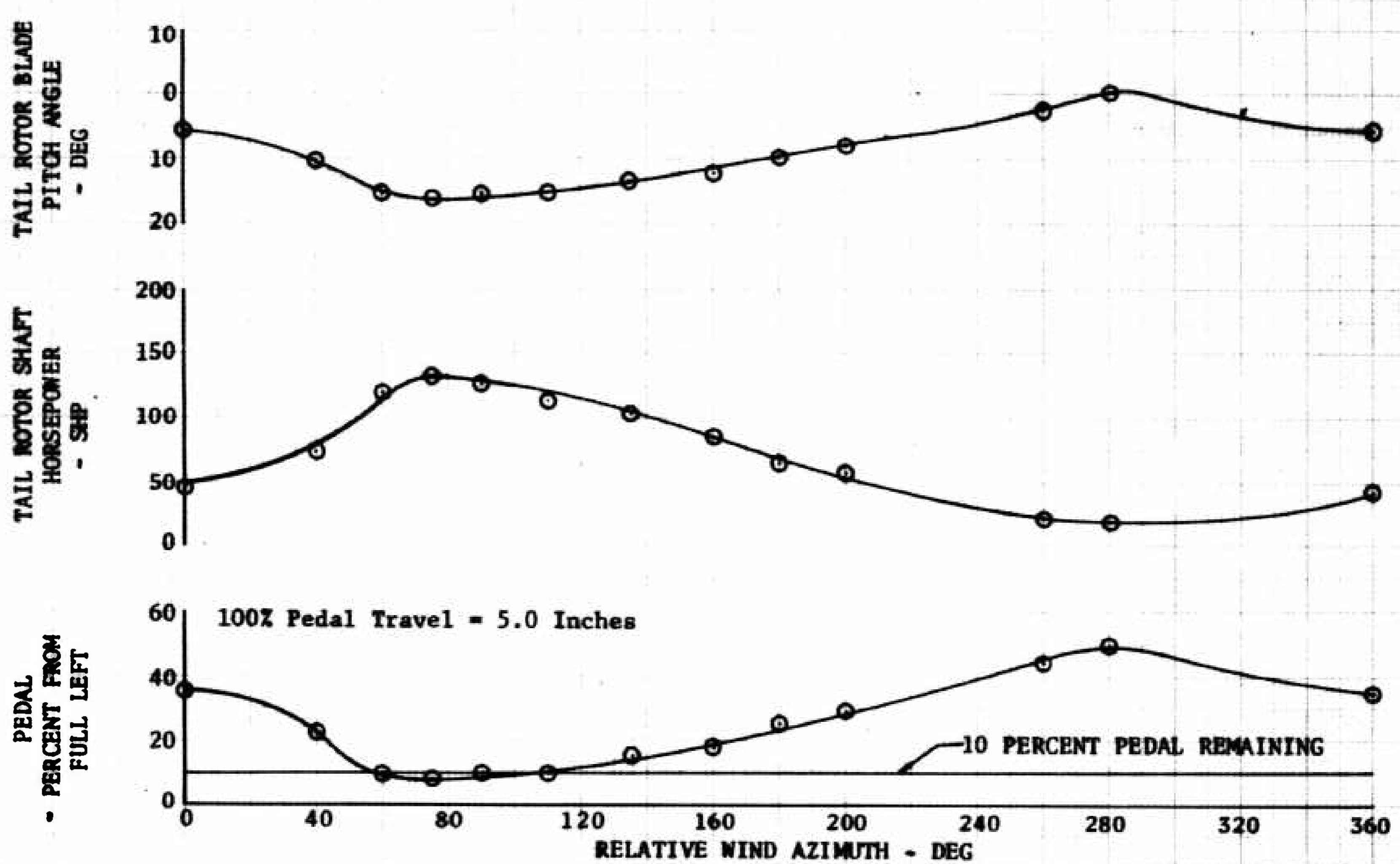


FIGURE NO 24
DIRECTIONAL CONTROL AT VARIOUS RELATIVE WIND AZIMUTHS
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR

AVG GROSS WEIGHT	AVG C.G. STATION	AVG DENSITY ALTITUDE	AVG TRUE AIRSPEED
8225 LBS	192.0 IN	4100 FT	20 KNOTS

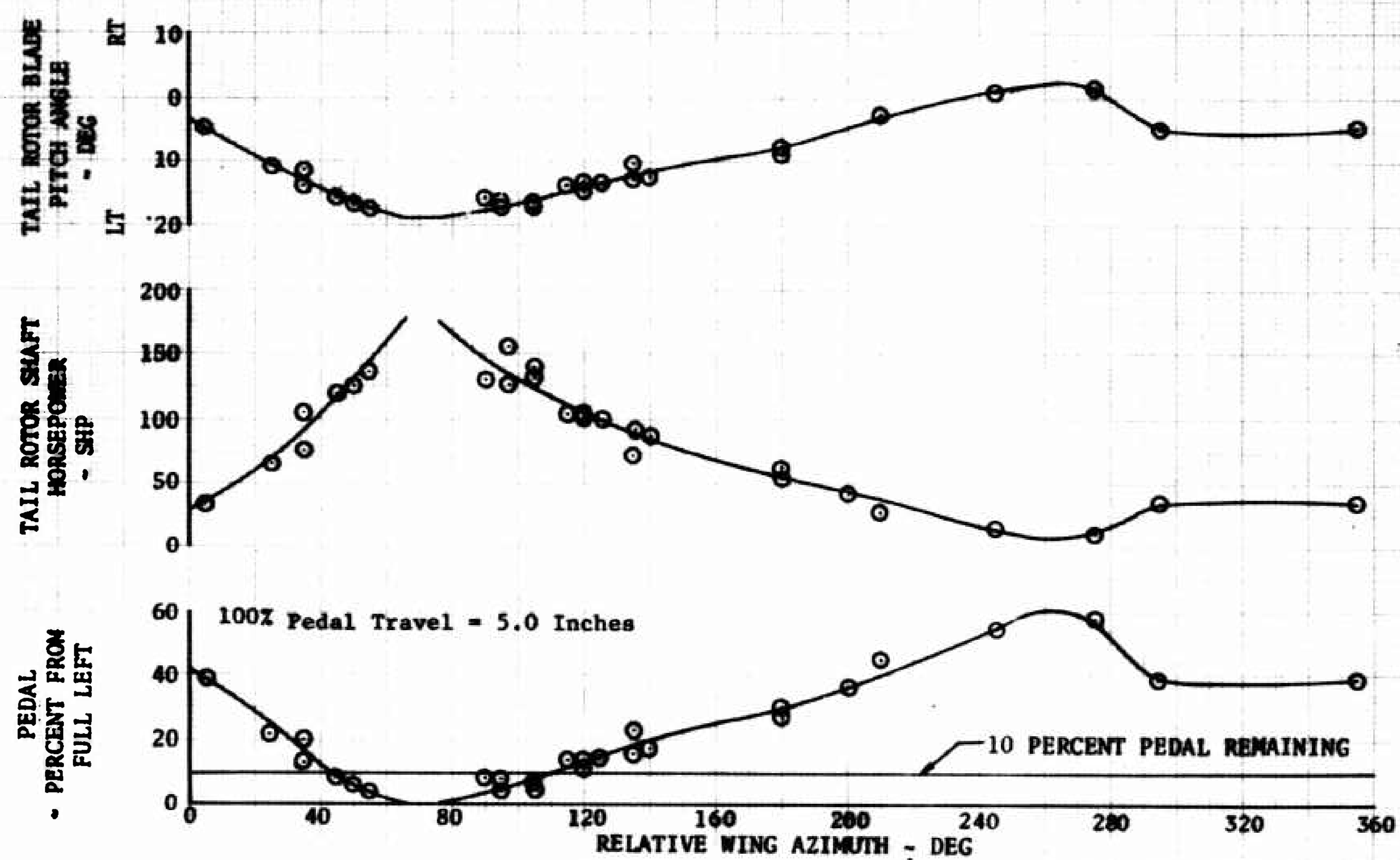


FIGURE NO 25

DIRECTIONAL CONTROL AT VARIOUS RELATIVE WIND AZIMUTHS

AH-1G USA S/N 66-15283

TRACTOR TAIL ROTOR

AVG GROSS WEIGHT	AVG C.G. STATION	AVG DENSITY ALTITUDE	AVG TRUE AIRSPEED
8565 LBS	192.5 IN	4460 FT	25 KNOTS

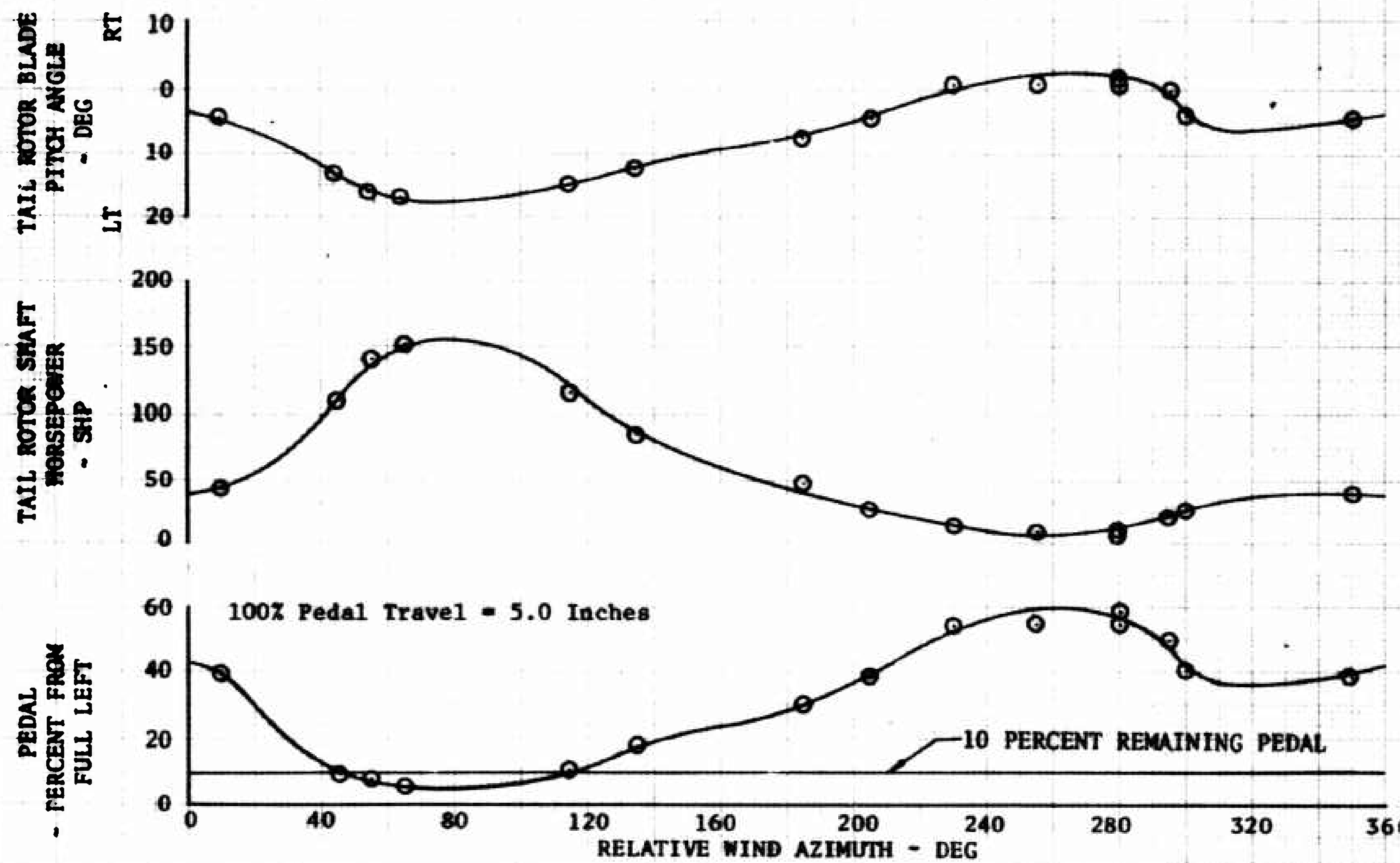


FIGURE NO 26
DIRECTIONAL CONTROL AT VARIOUS RELATIVE WIND AZIMUTHS
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR

AVG GROSS WEIGHT	AVG C.G. STATION	AVG DENSITY ALTITUDE	AVG TRUE AIRSPEED
8440 LBS	192.3 IN	5940 FT	28 KNOTS

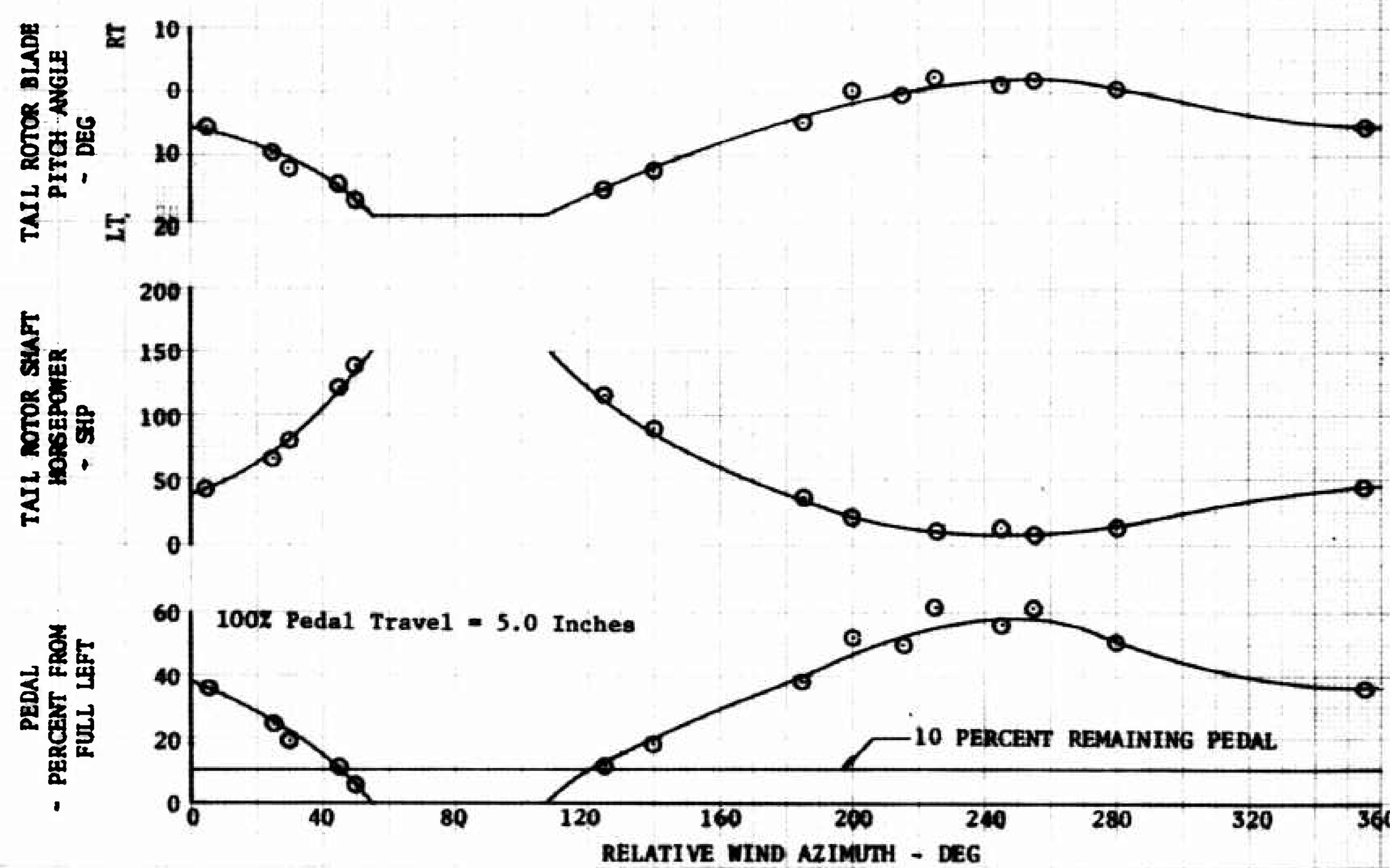


FIGURE NO 27
DIRECTIONAL CONTROL AT VARIOUS RELATIVE WIND AZIMUTHS
AH-IG USA S/N 66-15283
TRACTOR TAIL ROTOR

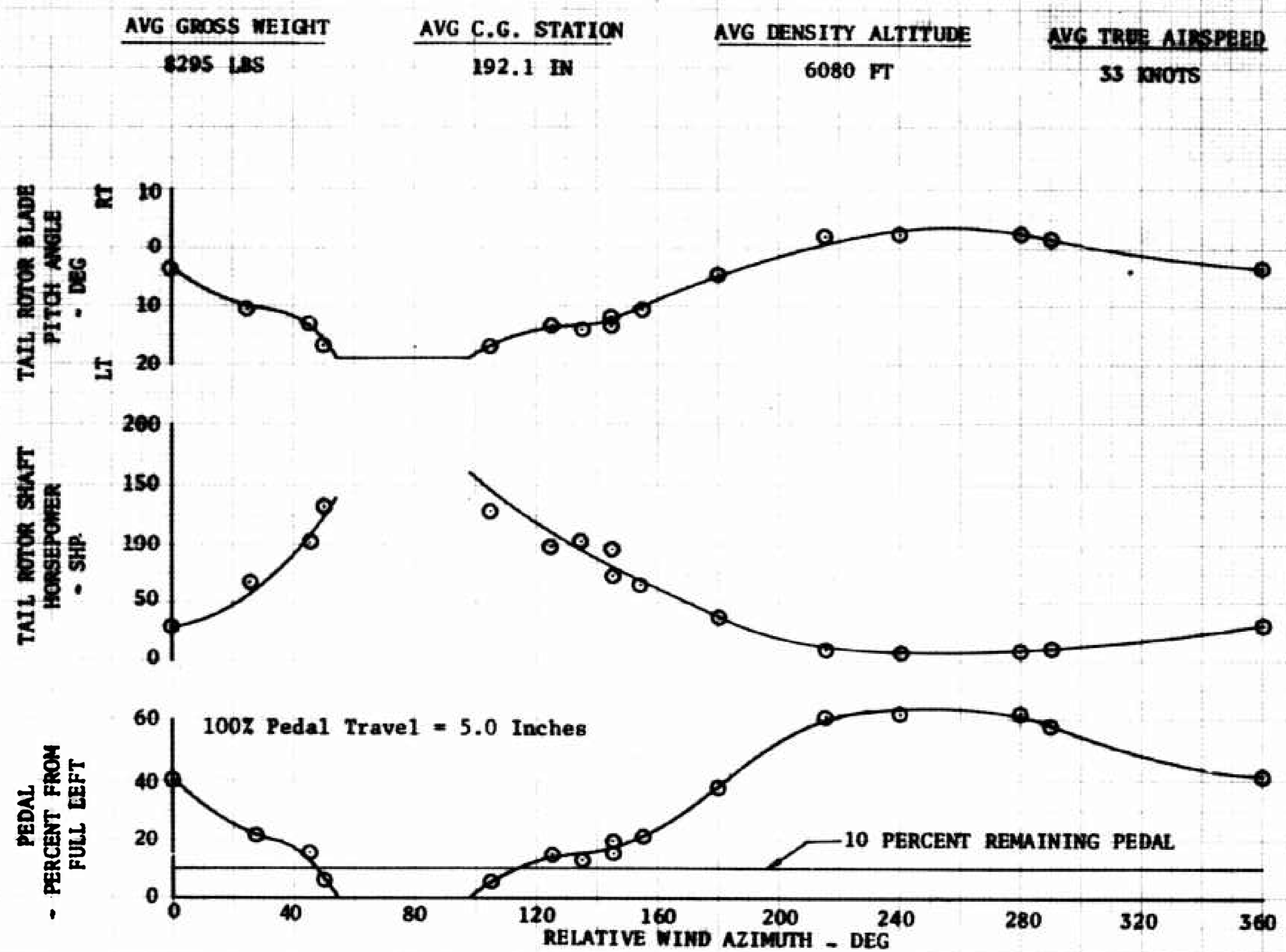


FIGURE NO 28
DIRECTIONAL CONTROL AT VARIOUS RELATIVE WIND AZIMUTHS
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR

AVG GROSS WEIGHT	AVG C.G. STATION	AVG DENSITY ALTITUDE	AVG TRUE AIRSPEED
9155 LBS	193.9 IN	5950 FT	9 KNOTS

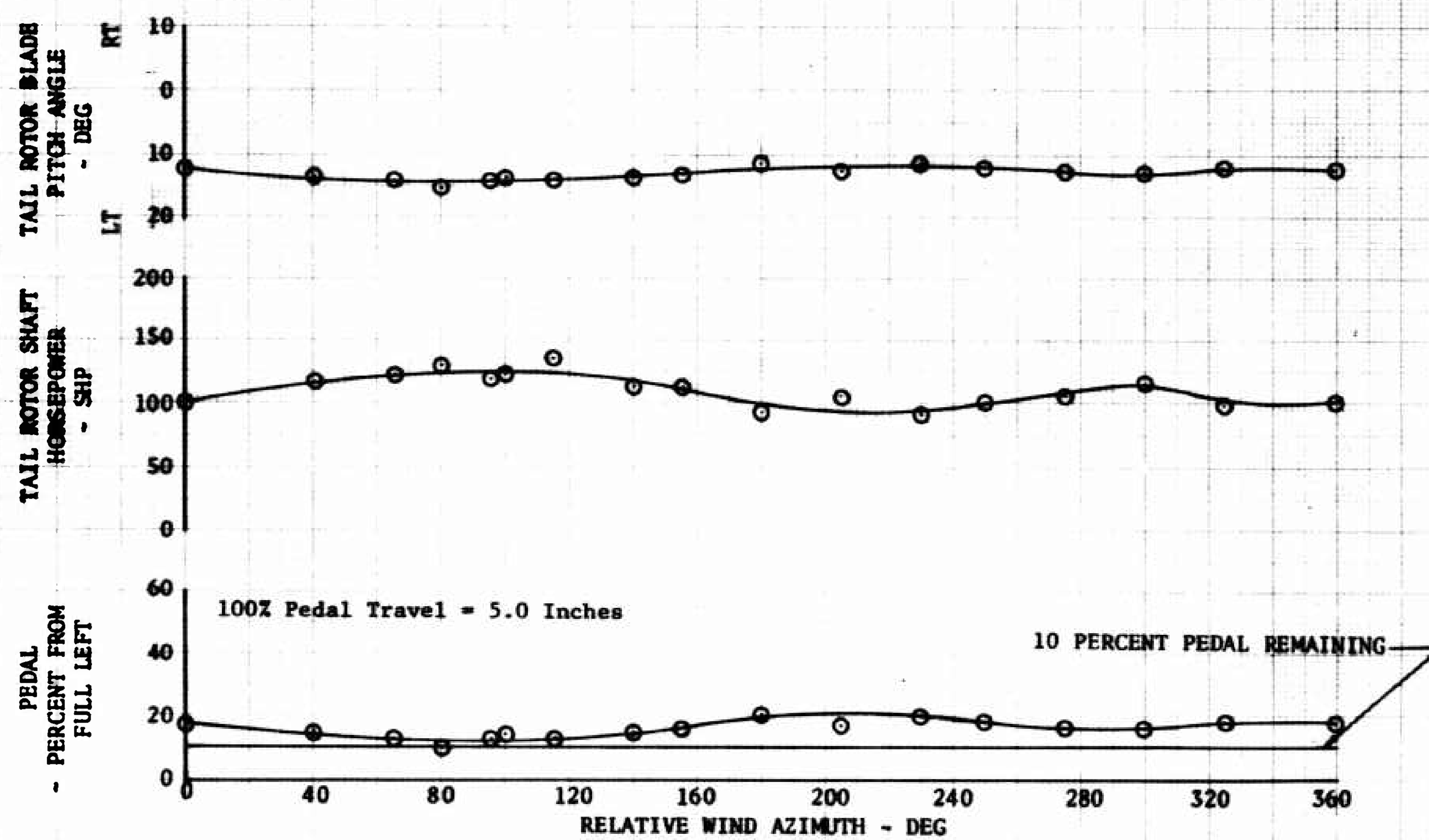


FIGURE NO 29
DIRECTIONAL CONTROL AT VARIOUS RELATIVE WIND AZIMUTHS
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR

AVG GROSS WEIGHT	AVG C.G. STATION	AVG DENSITY ALTITUDE	AVG TRUE AIRSPEED
9065 LBS	194.1 IN	5950 FT	13 KNOTS

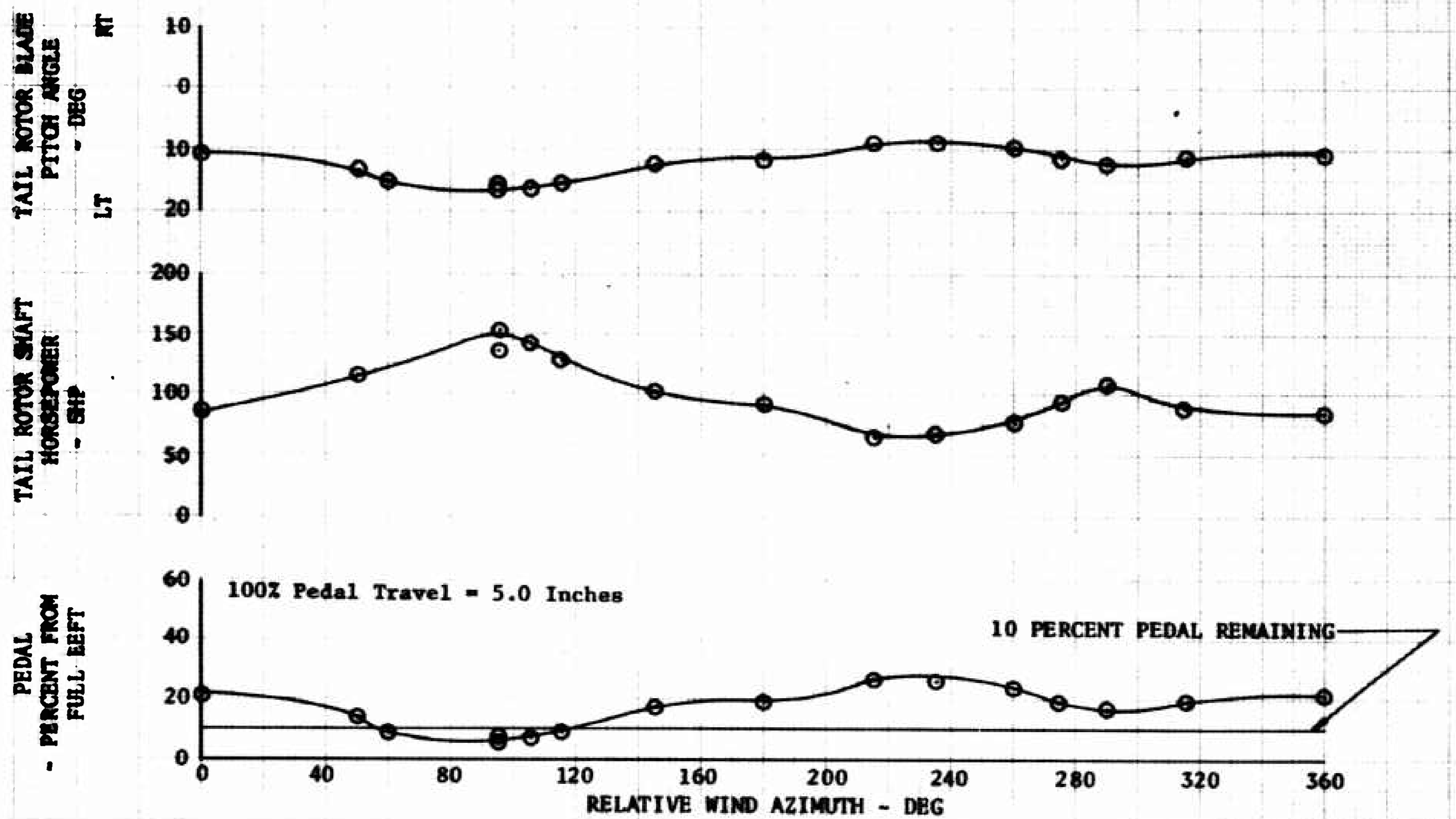


FIGURE NO 30
DIRECTIONAL CONTROL AT VARIOUS RELATIVE WIND AZIMUTHS
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR

AVG GROSS WEIGHT	AVG C.G. STATION	AVG DENSITY ALTITUDE	AVG TRUE AIRSPEED
8940 LBS	194.1 IN	5950 FT	18 KNOTS

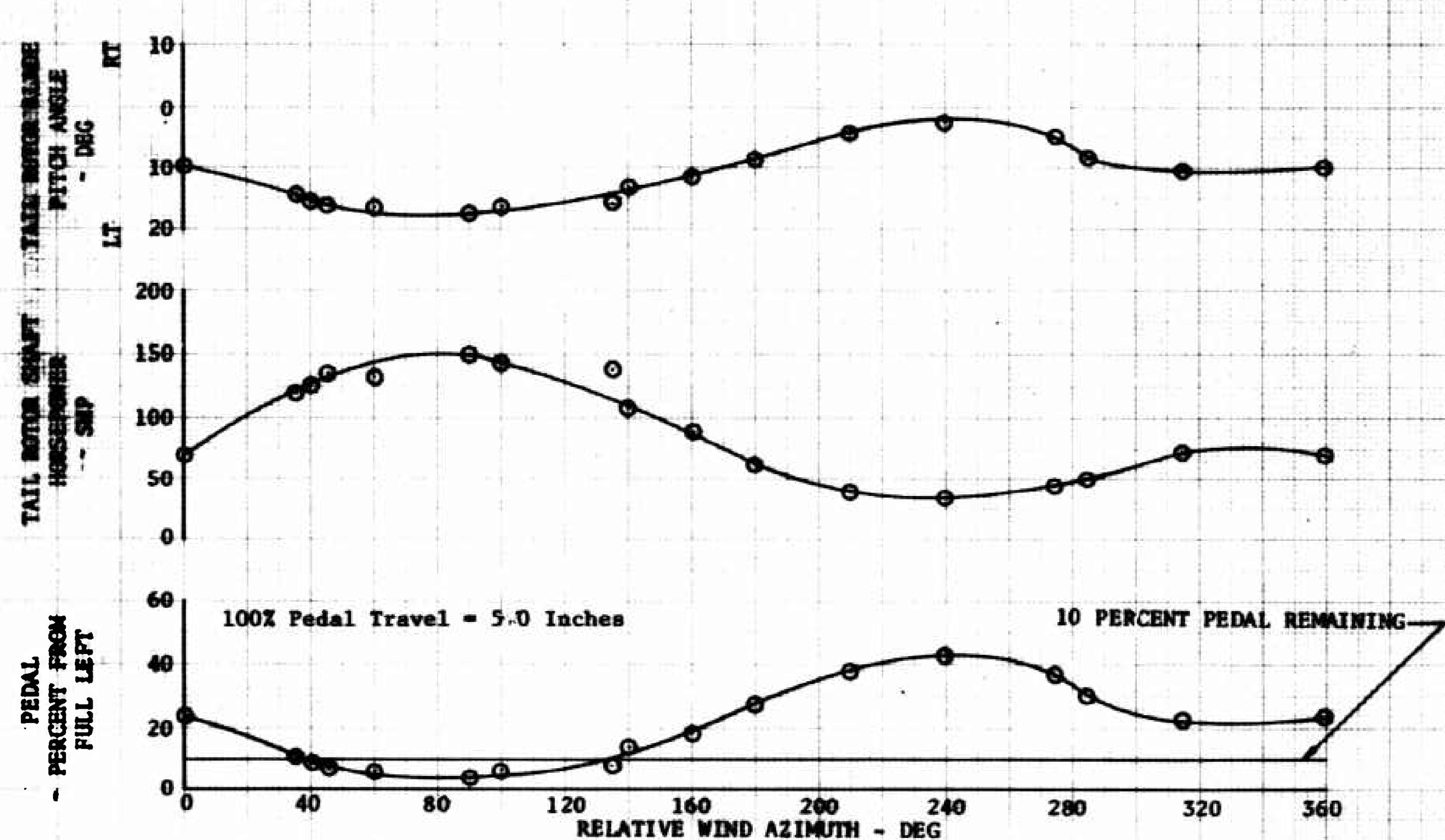


FIGURE NO 31
DIRECTIONAL CONTROL AT VARIOUS RELATIVE WIND AZIMUTHS
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR

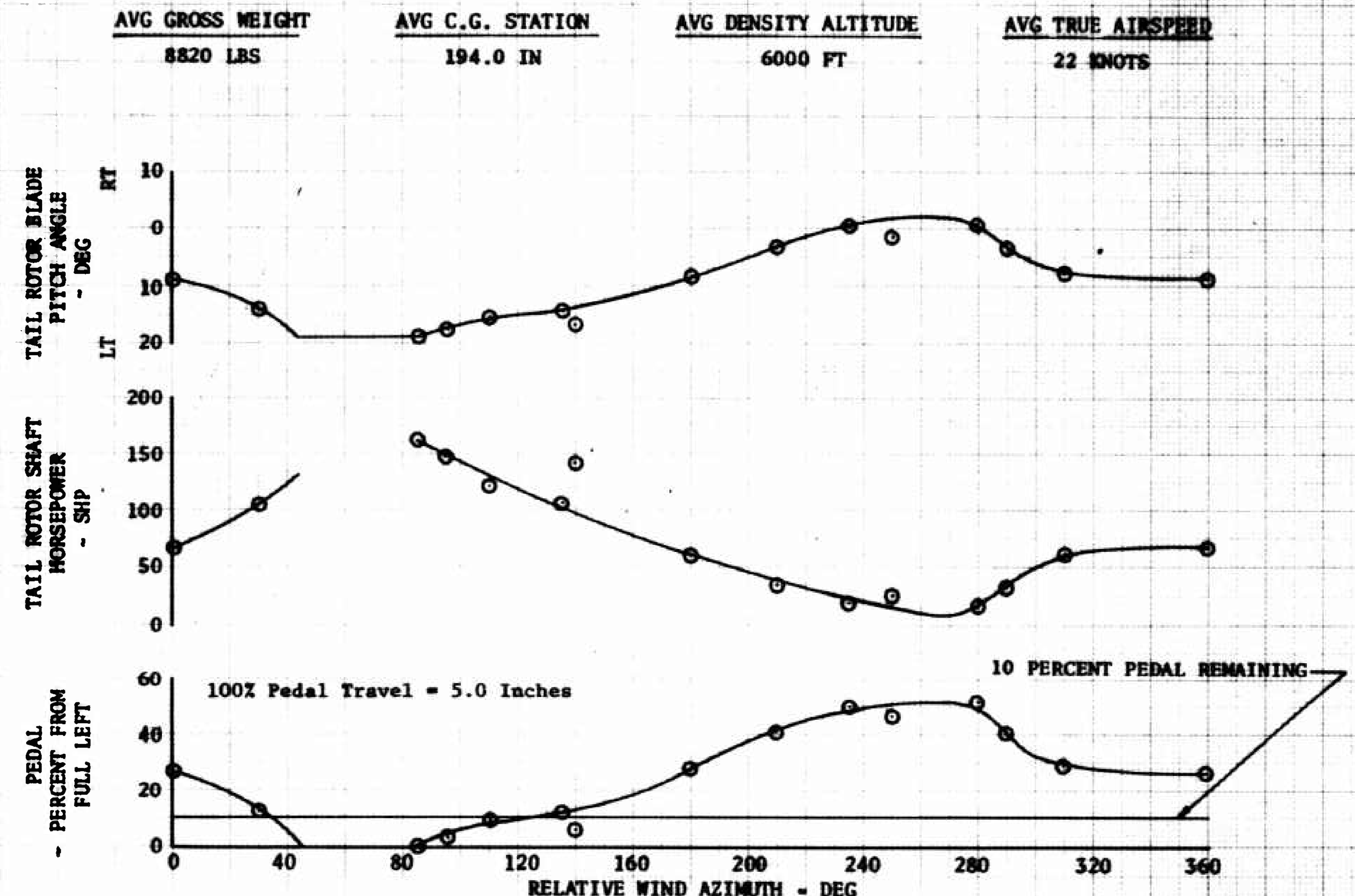


FIGURE NO 32
DIRECTIONAL CONTROL AT VARIOUS RELATIVE WIND AZIMUTHS
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR

AVG GROSS WEIGHT	AVG C.G. STATION	AVG DENSITY ALTITUDE	AVG TRUE AIRSPEED
8720 LBS	193.9 IN	6080 FT	26 KNOTS

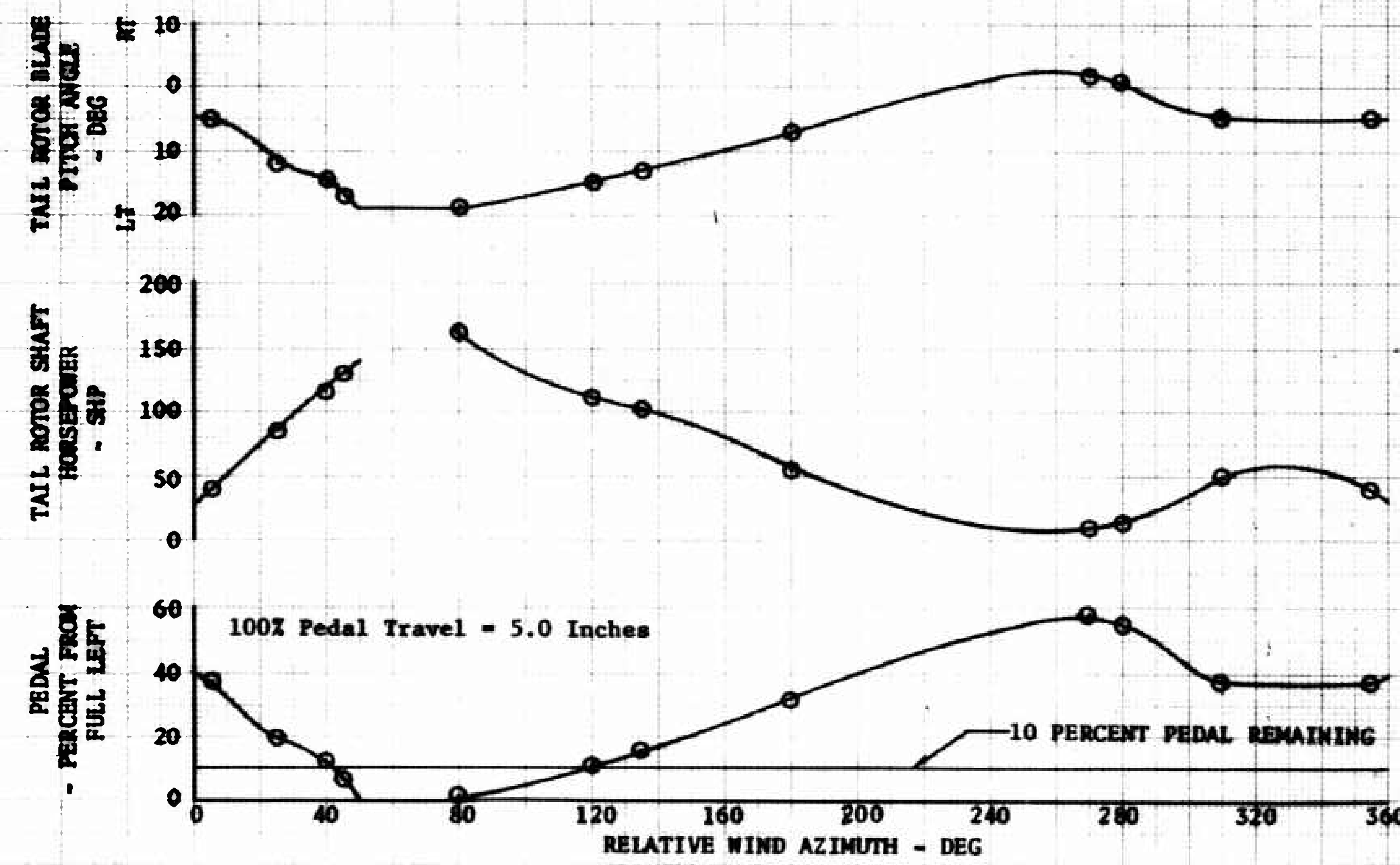


FIGURE NO 33
DIRECTIONAL CONTROL AT VARIOUS RELATIVE WIND AZIMUTHS
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR

AVG GROSS WEIGHT	AVG C.G. STATION	AVG DENSITY ALTITUDE	AVG TRUE AIRSPEED
8620 LBS	193.8 IN	6140 FT	31 KNOTS

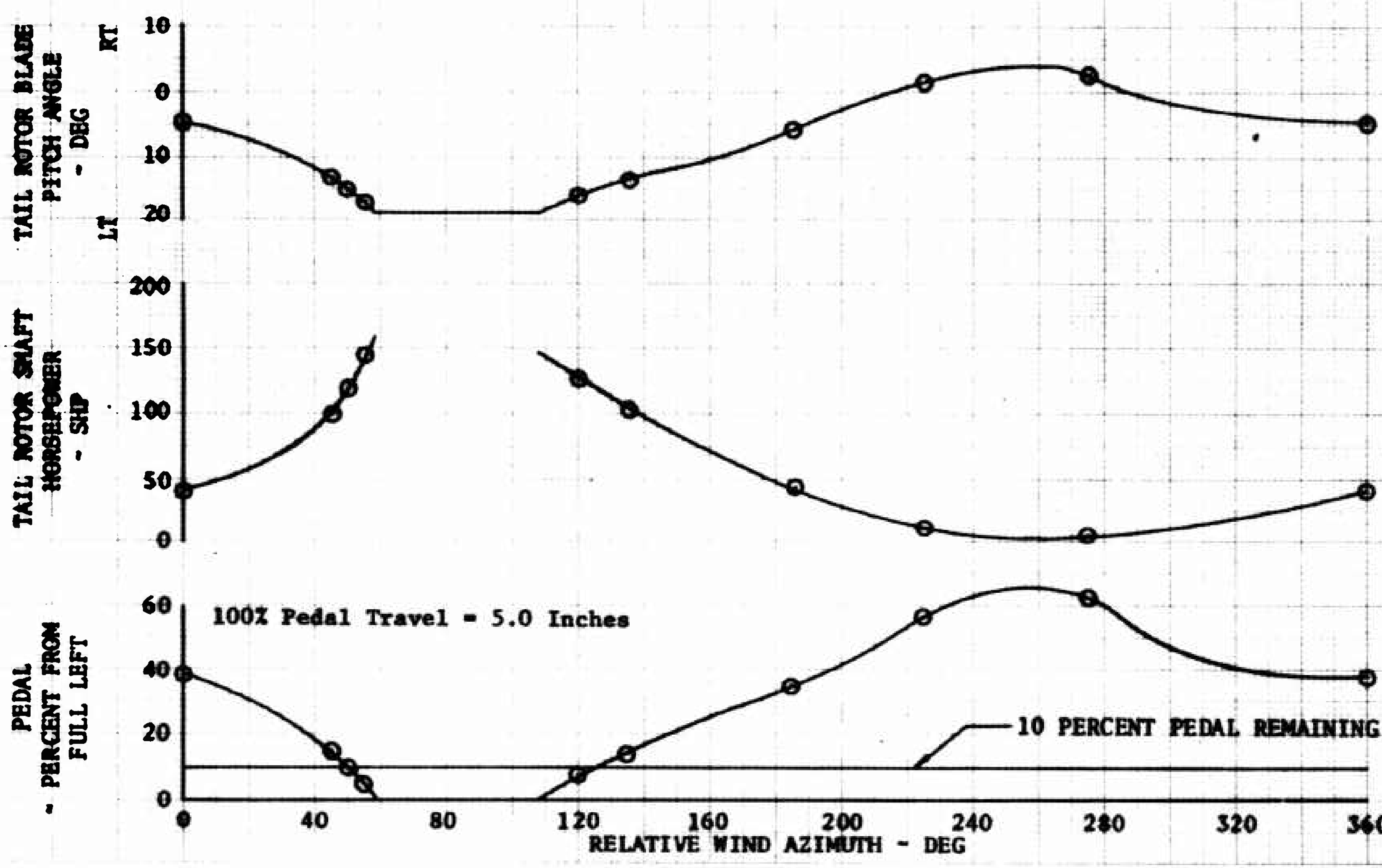


FIGURE NO 34
DIRECTIONAL CONTROL AT VARIOUS RELATIVE WIND AZIMUTHS
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR

AVG GROSS WEIGHT	AVG C.G. STATION	AVG DENSITY ALTITUDE	AVG TRUE AIRSPEED
8155 LBS	193.0 IN	10,100 FT	6 KNOTS

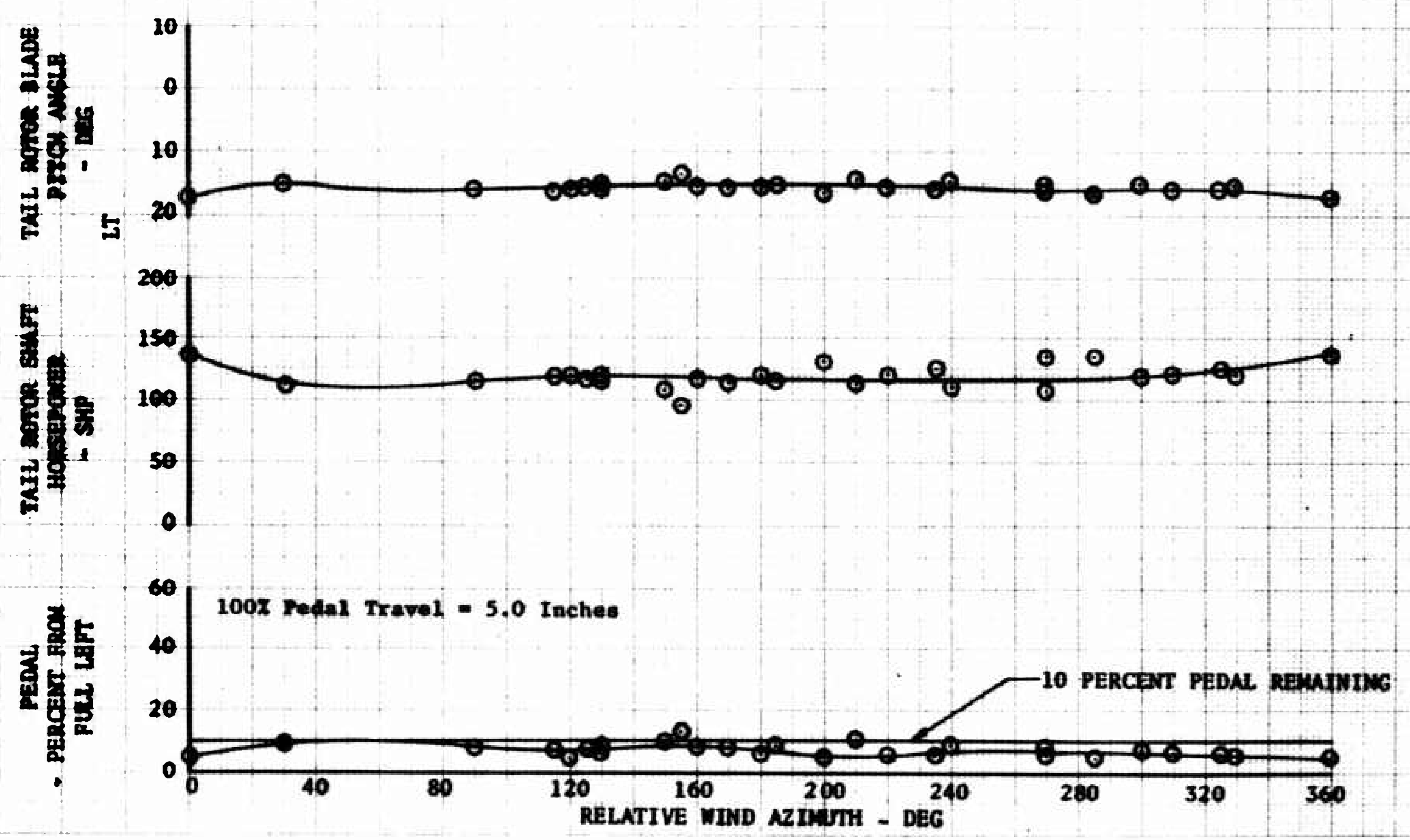


FIGURE NO 35
DIRECTIONAL CONTROL AT VARIOUS RELATIVE WIND AZIMUTHS
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR

AVG GROSS WEIGHT	AVG C.G. STATION	AVG DENSITY ALTITUDE	AVG TRUE AIRSPEED
8245 LBS	193.7 IN	10,360 FT	8.5 KNOTS

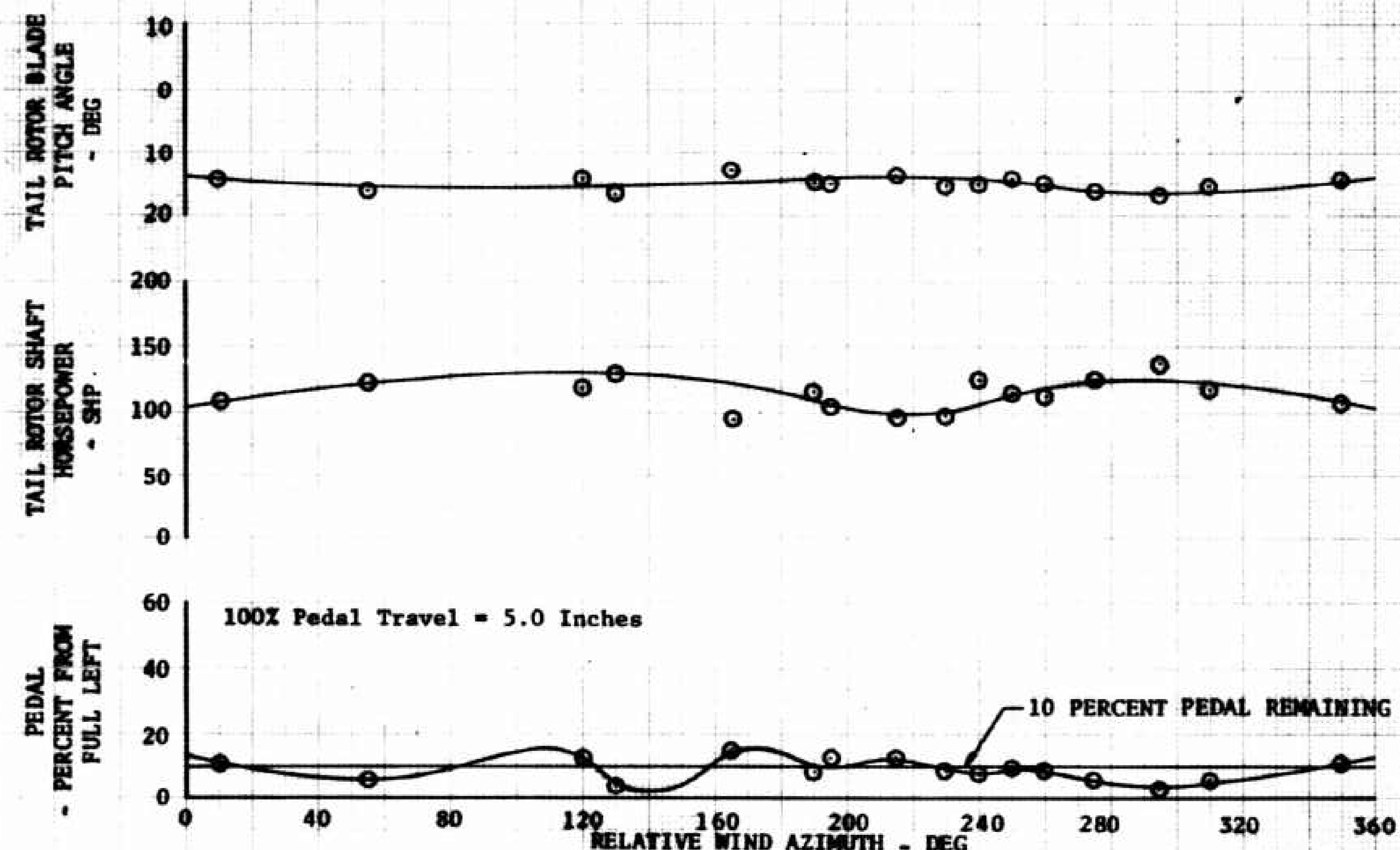
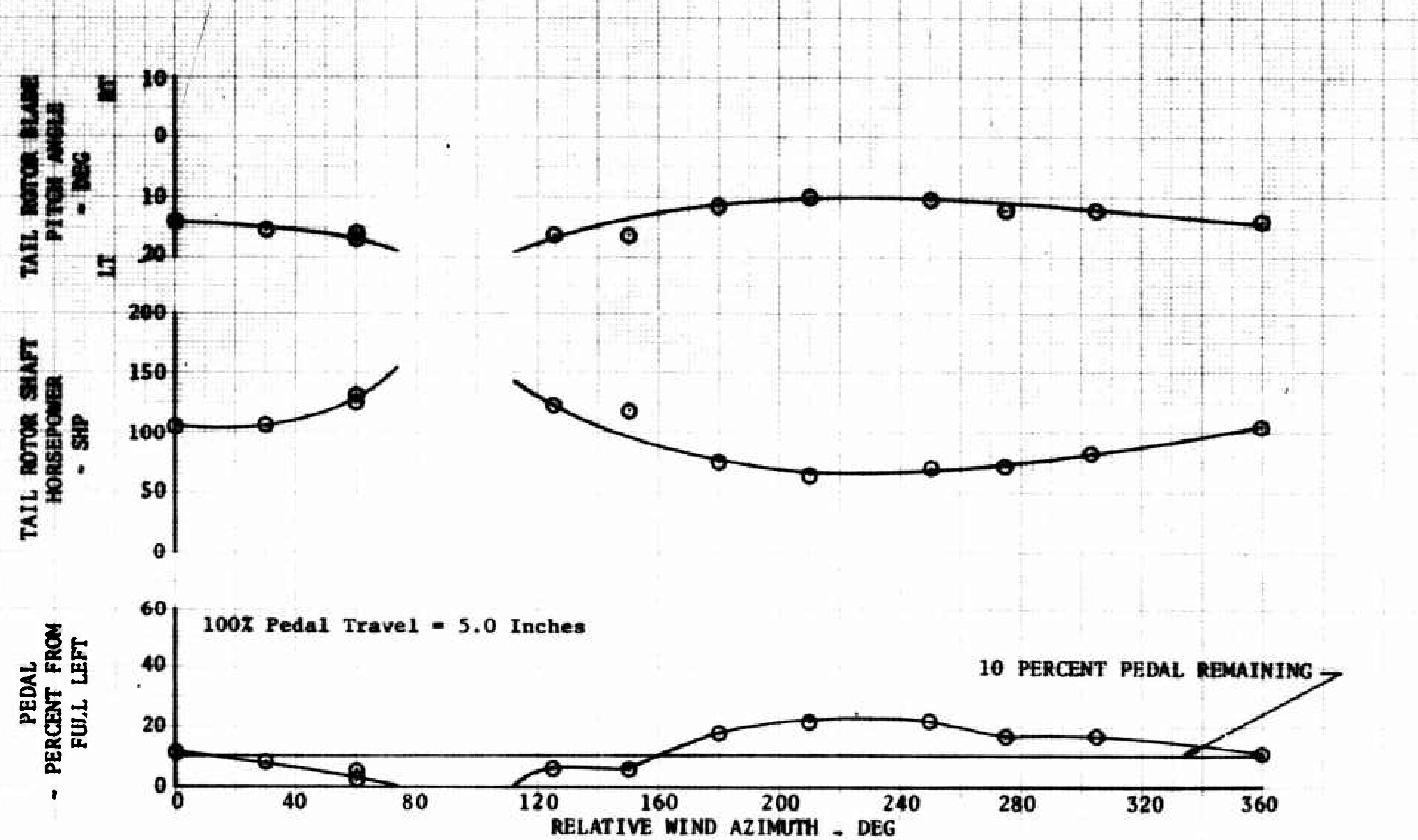


FIGURE NO 36
DIRECTIONAL CONTROL AT VARIOUS RELATIVE WIND AZIMUTHS
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR

AVG GROSS WEIGHT	AVG C.G. STATION	AVG DENSITY ALTITUDE	AVG TRUE AIRSPEED
8095 LBS	193.5 IN	10,280 FT	13.5 KNOTS



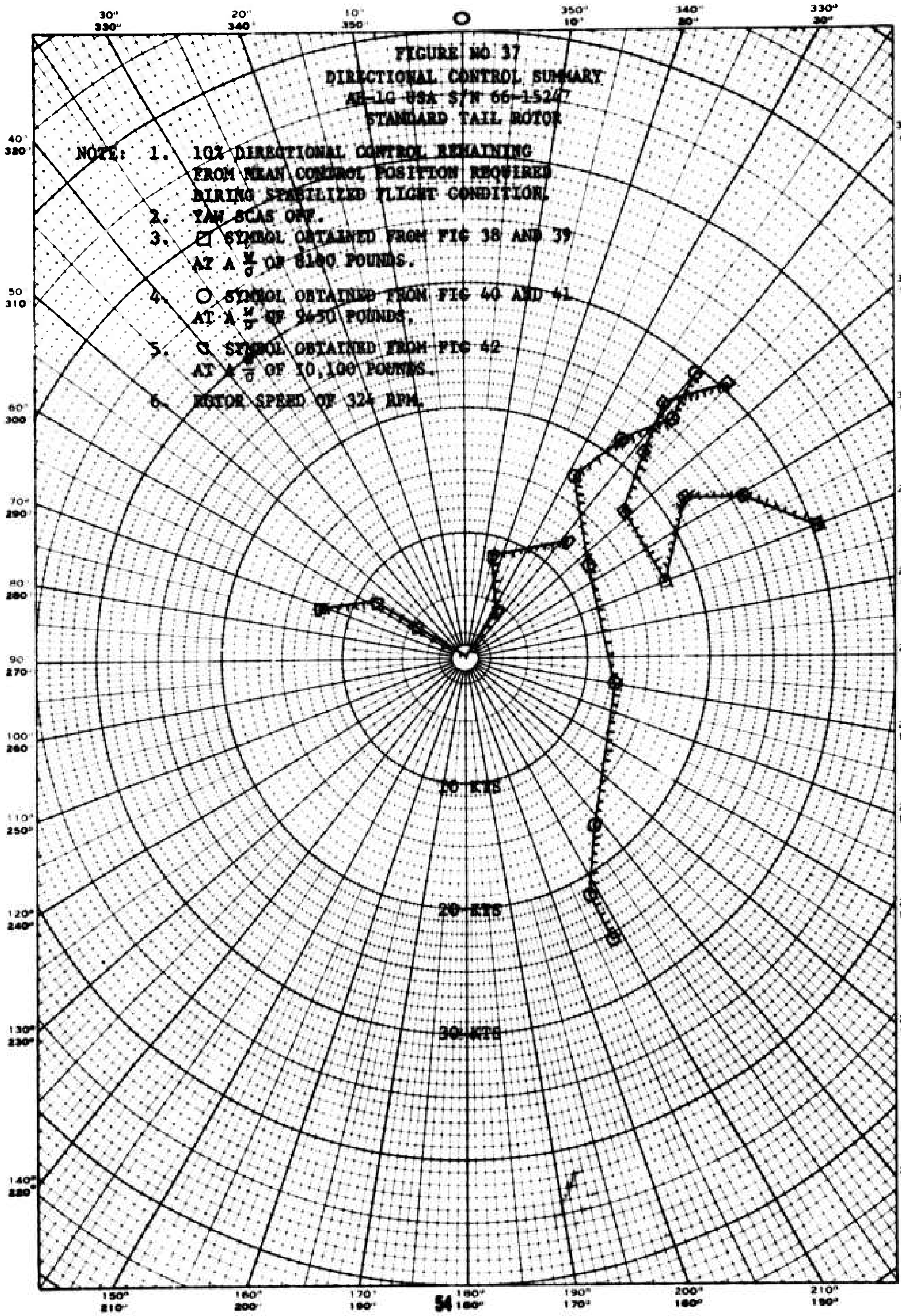


FIGURE NO. 37
DIRECTIONAL CONTROL SUMMARY
AH-1G USA S/N 66-15247
STANDARD TAIL ROTOR

NOTE: 1. 10% DIRECTIONAL CONTROL REMAINING FROM MEAN CONTROL POSITION REQUIRED DURING STABILIZED FLIGHT CONDITION.
2. YAW SCAS OFF.
3. ☐ SYMBOL OBTAINED FROM FIG 38 AND 39 AT A $\frac{W}{\sigma}$ OF 8100 POUNDS.
4. ○ SYMBOL OBTAINED FROM FIG 40 AND 41 AT A $\frac{W}{\sigma}$ OF 9450 POUNDS.
5. ◇ SYMBOL OBTAINED FROM FIG 42 AT A $\frac{W}{\sigma}$ OF 10,100 POUNDS.
6. ROTOR SPEED OF 324 RPM.

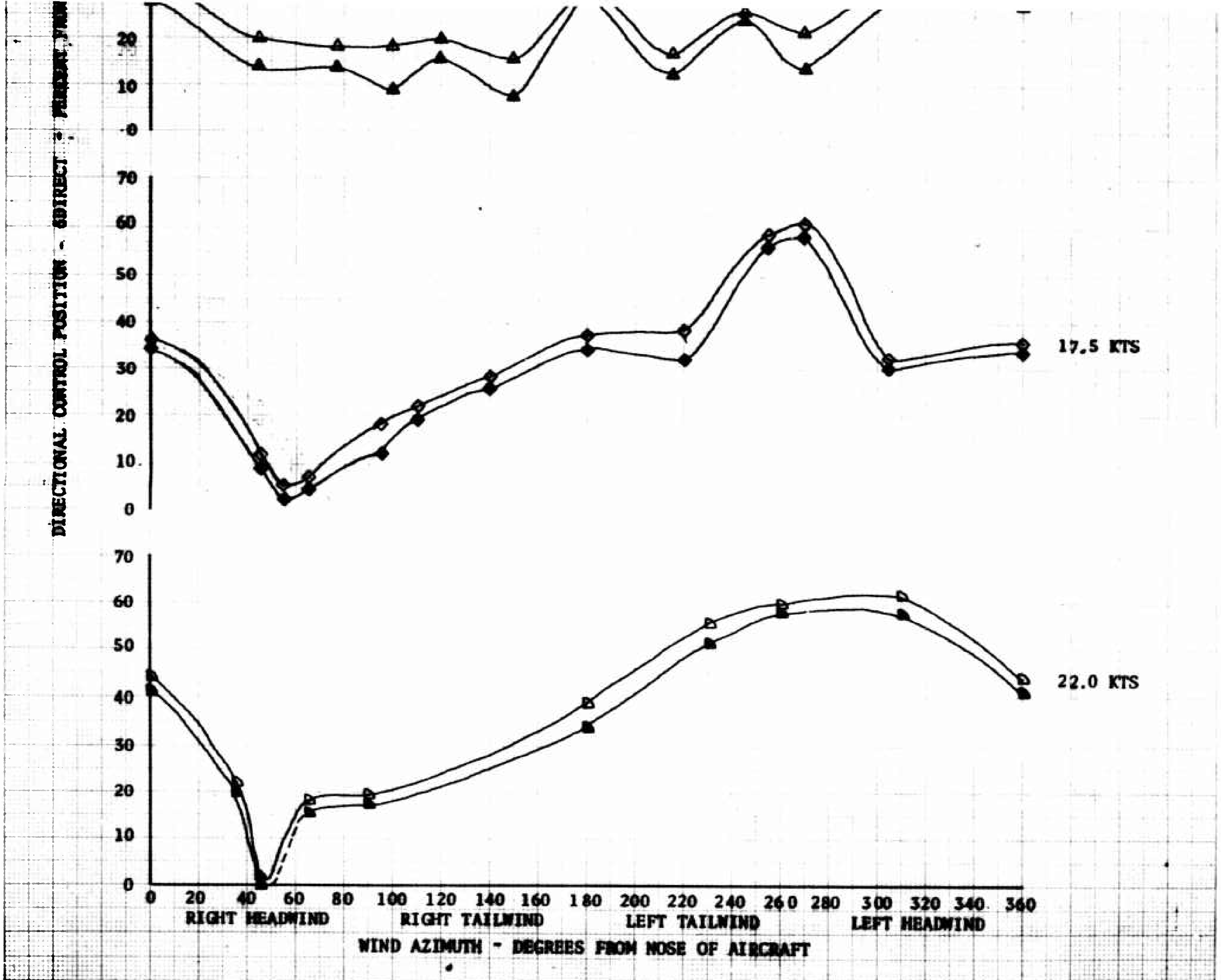

DIRECTIONAL CONTROL POSITION - δDIRECT - PERCENT FROM
17.5 KTS
22.0 KTS
RIGHT HEADWIND
RIGHT TAILWIND
LEFT TAILWIND
LEFT HEADWIND
WIND AZIMUTH - DEGREES FROM NOSE OF AIRCRAFT

FIGURE NO 38
DIRECTIONAL CONTROL REQUIRED VS WIND AZIMUTH
AH-1G S/N 66-15247
HEAVY SCOUT CONFIGURATION

SYMBOL	ROTOR - RPM	G.W. - LB	C.G. - IN LONG	H_D FT	AIRSPEED - KTAS
○	324	8110	200.7 (AFT)	130	4.5
□	324	8000	200.7 (AFT)	130	9.0
△	324	8080	200.5 (AFT)	130	13.0
◇	324	8060	200.4 (AFT)	130	17.5
◁	324	8060	200.3 (AFT)	130	22.0

NOTE:
1. STANDARD TAIL ROTOR CONFIGURATION.
2. FULL LEFT DIRECTIONAL CONTROL = 19° TAIL ROTOR PITCH.
3. OPEN SYMBOLS DENOTE MEAN DIRECTIONAL CONTROL POSITION REQUIRED TO STABILIZE AIRCRAFT.
4. SOLID SYMBOLS DENOTE MAXIMUM LEFT DIRECTIONAL CONTROL POSITION ENCOUNTERED WHEN STABILIZING AIRCRAFT.
5. TEST WAS CONDUCTED IGE AT AN AVERAGE SKID HEIGHT OF 10 FEET.

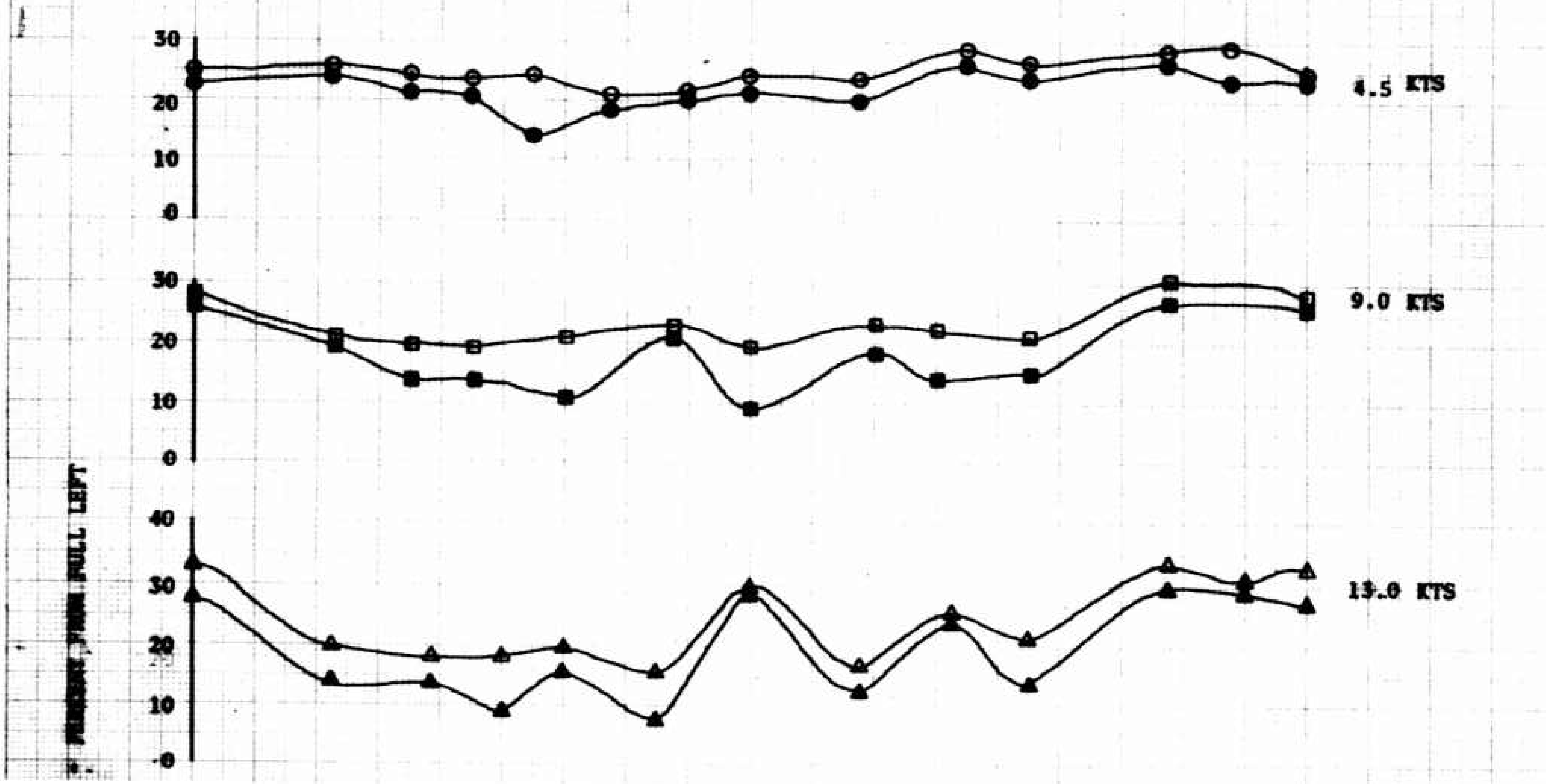
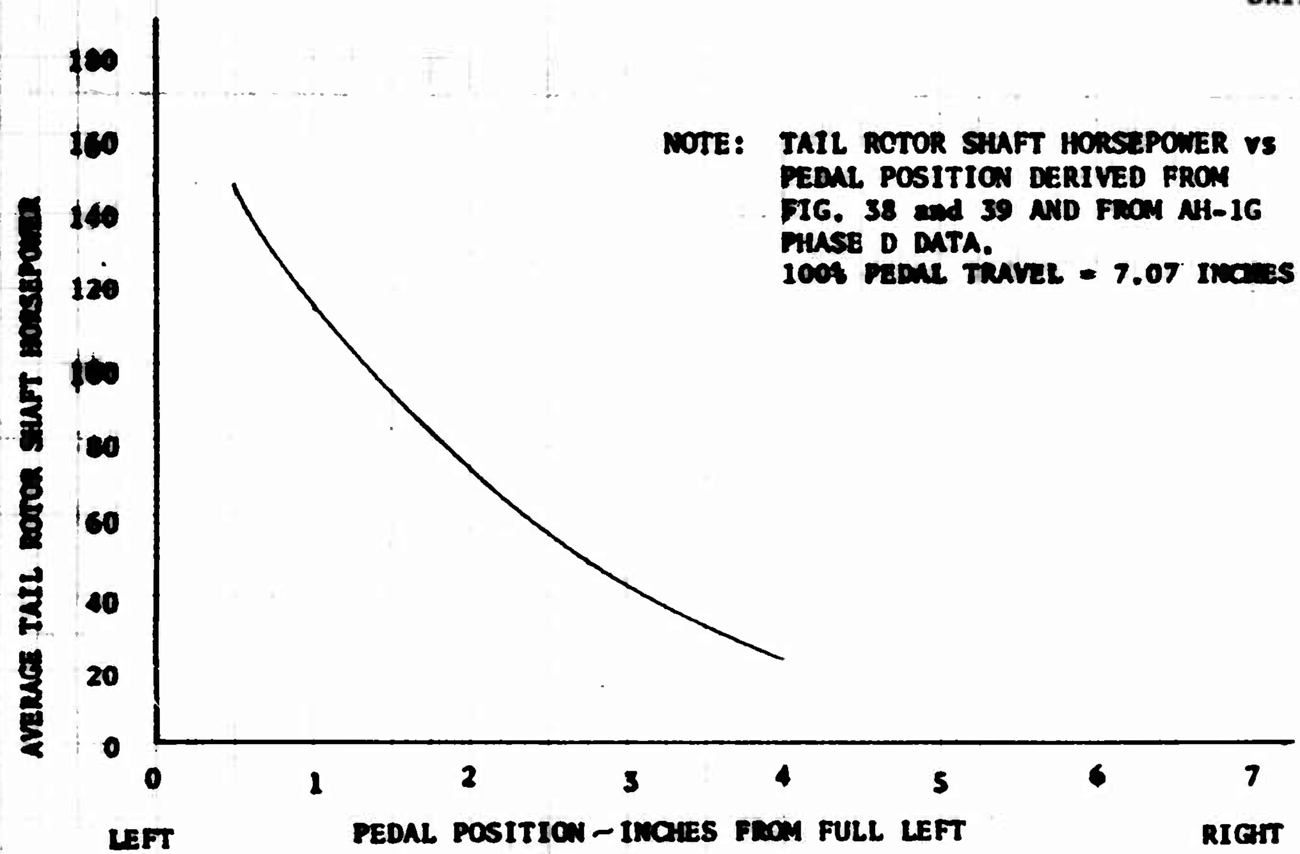
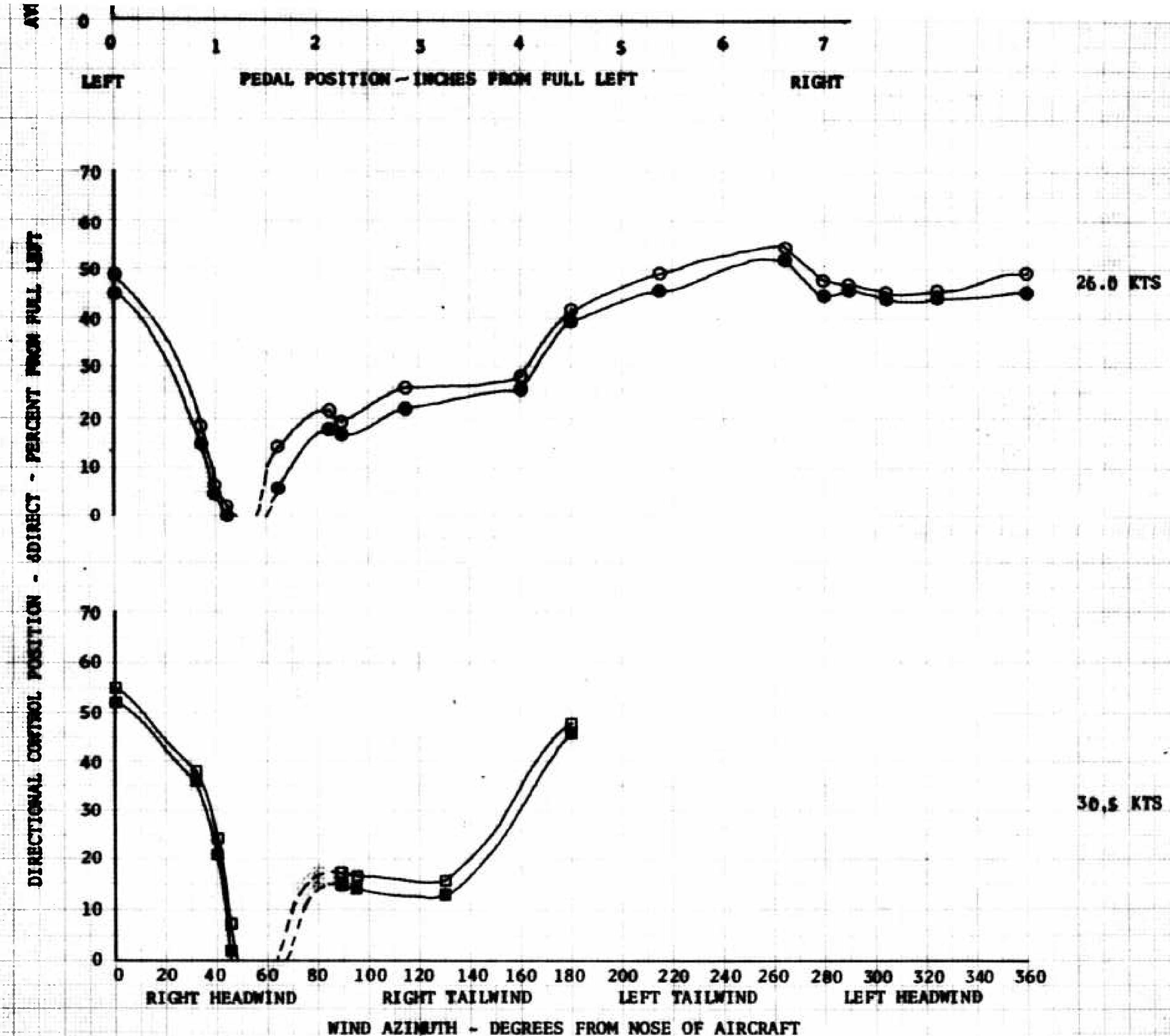


FIGURE NO 39
DIRECTIONAL CONTROL REQUIRED VS WIND AZIMUTH
AH-1G S/N 66-15247
HEAVY SCOUT CONFIGURATION

SYMBOL	ROTOR - RPM	G.W. - LB	C.G. - IN LONG	H_D FT	AIRSPEED - KTAS
○	324	8020	200.3 (AFT)	180	26.0
□	324	8080	200.1 (AFT)	230	30.5

NOTE:
1. STANDARD TAIL ROTOR CONFIGURATION.
2. FULL LEFT DIRECTIONAL CONTROL = 19° TAIL ROTOR PITCH.
3. OPEN SYMBOLS DENOTE MEAN DIRECTIONAL CONTROL POSITION REQUIRED TO STABILIZE AIRCRAFT.
4. SOLID SYMBOLS DENOTE MAXIMUM LEFT DIRECTIONAL CONTROL POSITION ENCOUNTERED WHEN STABILIZING AIRCRAFT.
5. TEST WAS CONDUCTED IGE AT AN AVERAGE SKID HEIGHT OF 10 FEET.



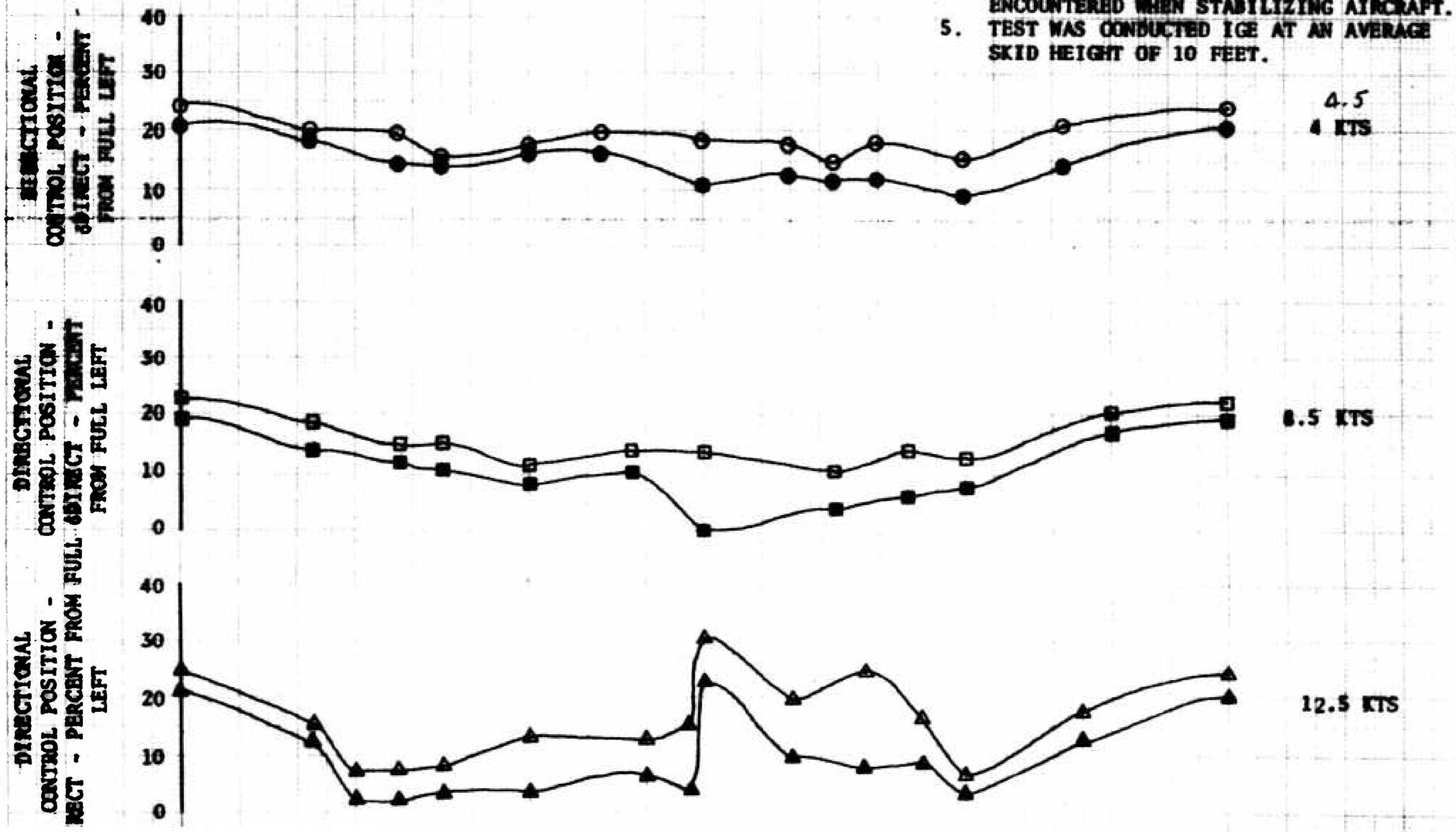


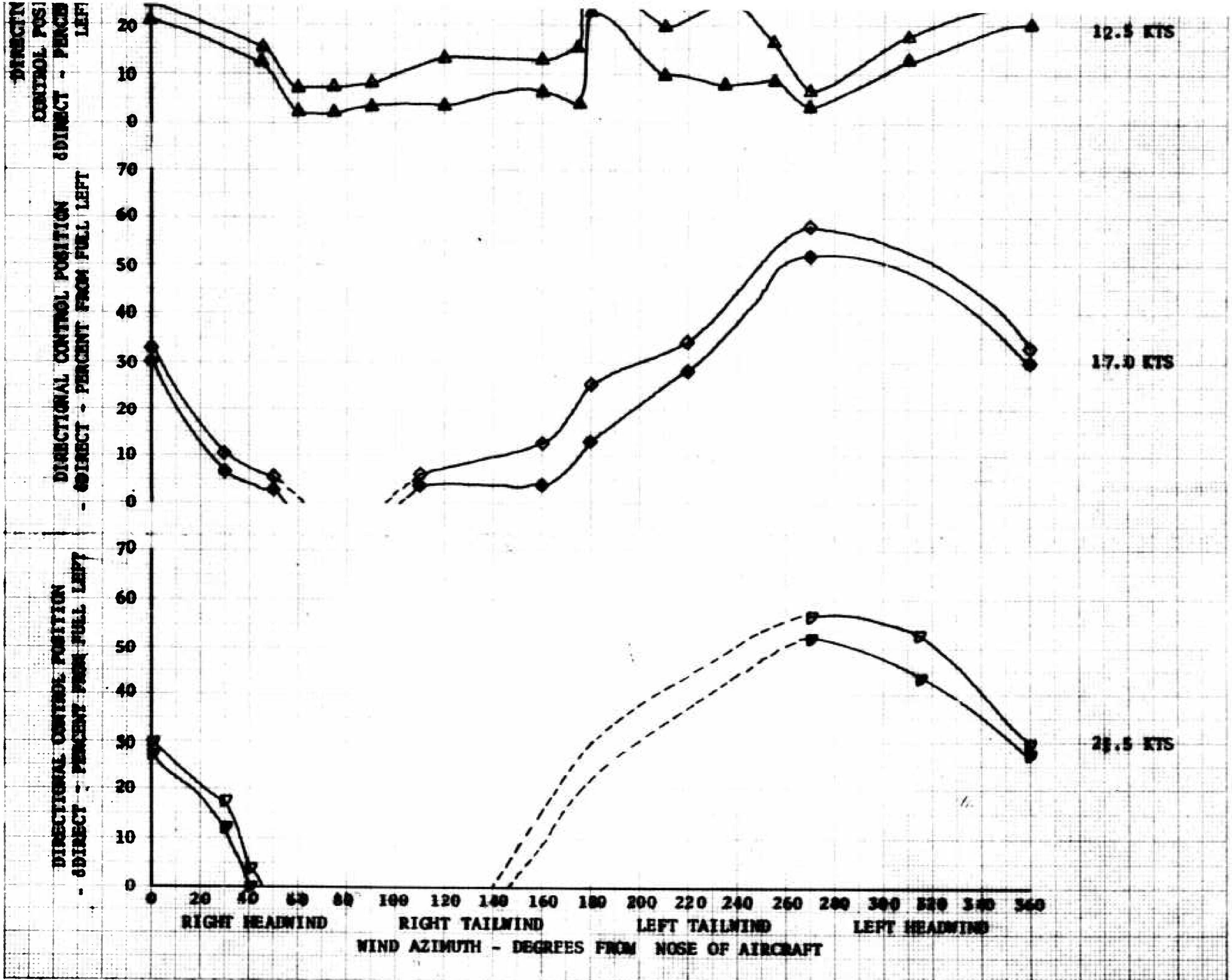
0 1 2 3 4 5 6 7
LEFT
PEDAL POSITION – INCHES FROM FULL LEFT
RIGHT
DIRECTIONAL CONTROL POSITION - δDIRECT - PERCENT FROM FULL LEFT
70 60 50 40 30 20 10 0
26.0 KTS
30.5 KTS
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
RIGHT HEADWIND
RIGHT TAILWIND
LEFT TAILWIND
LEFT HEADWIND
WIND AZIMUTH - DEGREES FROM NOSE OF AIRCRAFT

FIGURE NO 40
DIRECTIONAL CONTROL REQUIRED VS WIND AZIMUTH
AH-1G S/N 66-15247
HEAVY SCOUT CONFIGURATION

SYMBOL	ROTOR - RPM	G.W. - LB	C.G. - IN LONG	H_D FT	AIRSPEED - KTAS
○	324	8090	200.9 (AFT)	5130	4.5
□	324	8070	200.8 (AFT)	5260	8.5
△	324	8090	200.8 (AFT)	5240	12.5
◇	324	8040	200.6 (AFT)	5210	17.8
◁	324	8050	200.5 (AFT)	5350	21.5

NOTE:
1. STANDARD TAIL ROTOR CONFIGURATION.
2. FULL LEFT DIRECTIONAL CONTROL = 19° TAIL ROTOR PITCH.
3. OPEN SYMBOLS DENOTE MEAN DIRECTIONAL CONTROL POSITION REQUIRED TO STABILIZE AIRCRAFT.
4. SOLID SYMBOLS DENOTE MAXIMUM LEFT DIRECTIONAL CONTROL POSITION ENCOUNTERED WHEN STABILIZING AIRCRAFT.
5. TEST WAS CONDUCTED IGE AT AN AVERAGE SKID HEIGHT OF 10 FEET.





DIRECTIONAL CONTROL POSITION δDIRECT - PERCENT FROM FULL LEFT
12.5 KTS
17.0 KTS
28.5 KTS
RIGHT HEADWIND
RIGHT TAILWIND
LEFT TAILWIND
LEFT HEADWIND
WIND AZIMUTH - DEGREES FROM NOSE OF AIRCRAFT

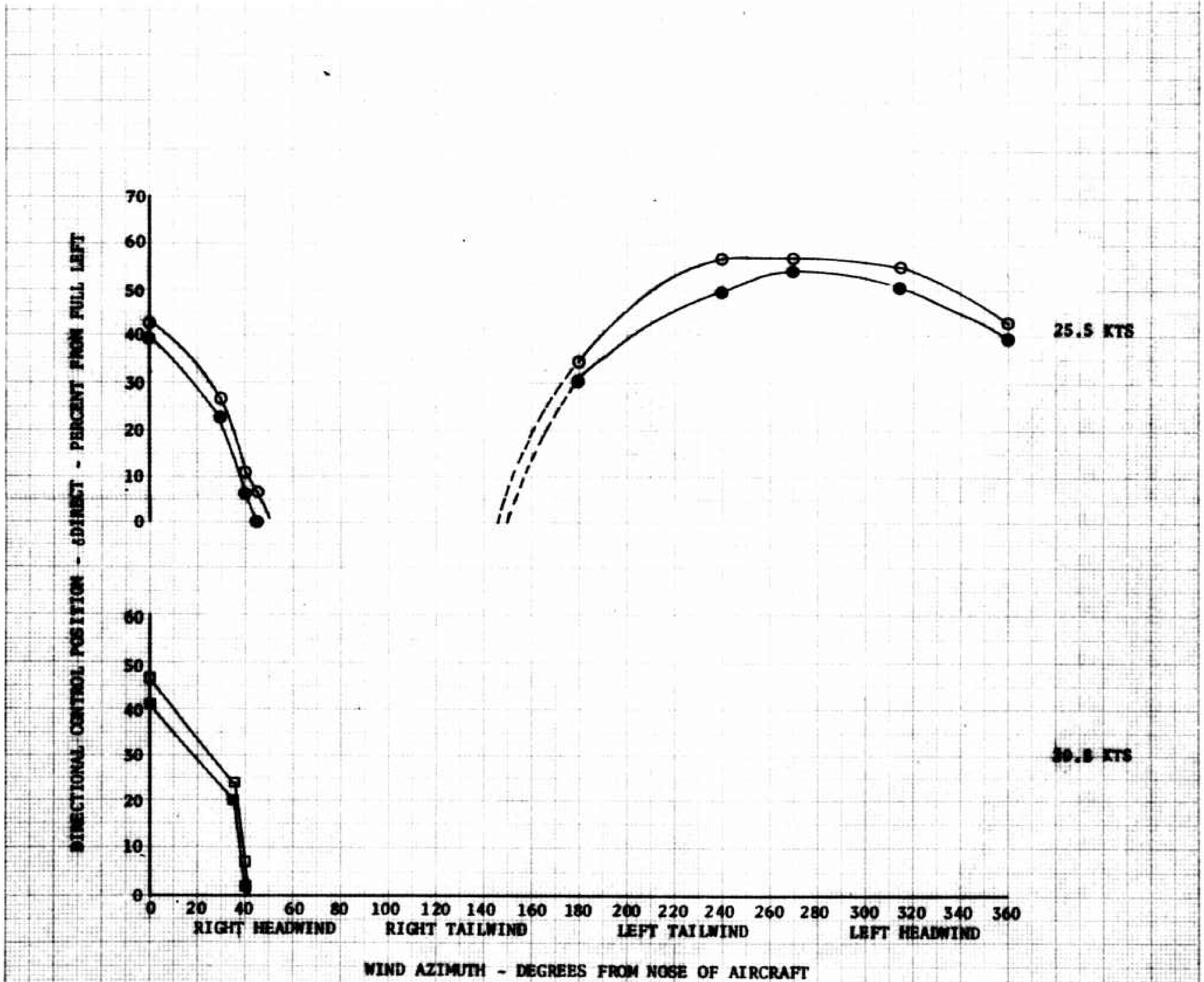

DIRECTIONAL CONTROL POSITION - δDIRECT - PERCENT FROM FULL LEFT
0
10
20
30
40
50
60
70
25.5 KTS
30.8 KTS
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
RIGHT HEADWIND
RIGHT TAILWIND
LEFT TAILWIND
LEFT HEADWIND
WIND AZIMUTH - DEGREES FROM NOSE OF AIRCRAFT

FIGURE NO 42
DIRECTIONAL CONTROL REQUIRED VS WIND AZIMUTH
AH-1G S/N 66-15247
HEAVY SCOUT CONFIGURATION

SYMBOL	ROTOR - RPM	G.W. - LB	C.G. - IN LONG	H_D FT	AIRSPEED - KTAS
○	324	8040	200.5 (AFT)	5350	25.5
□	324	7990	200.5 (AFT)	5350	29.5

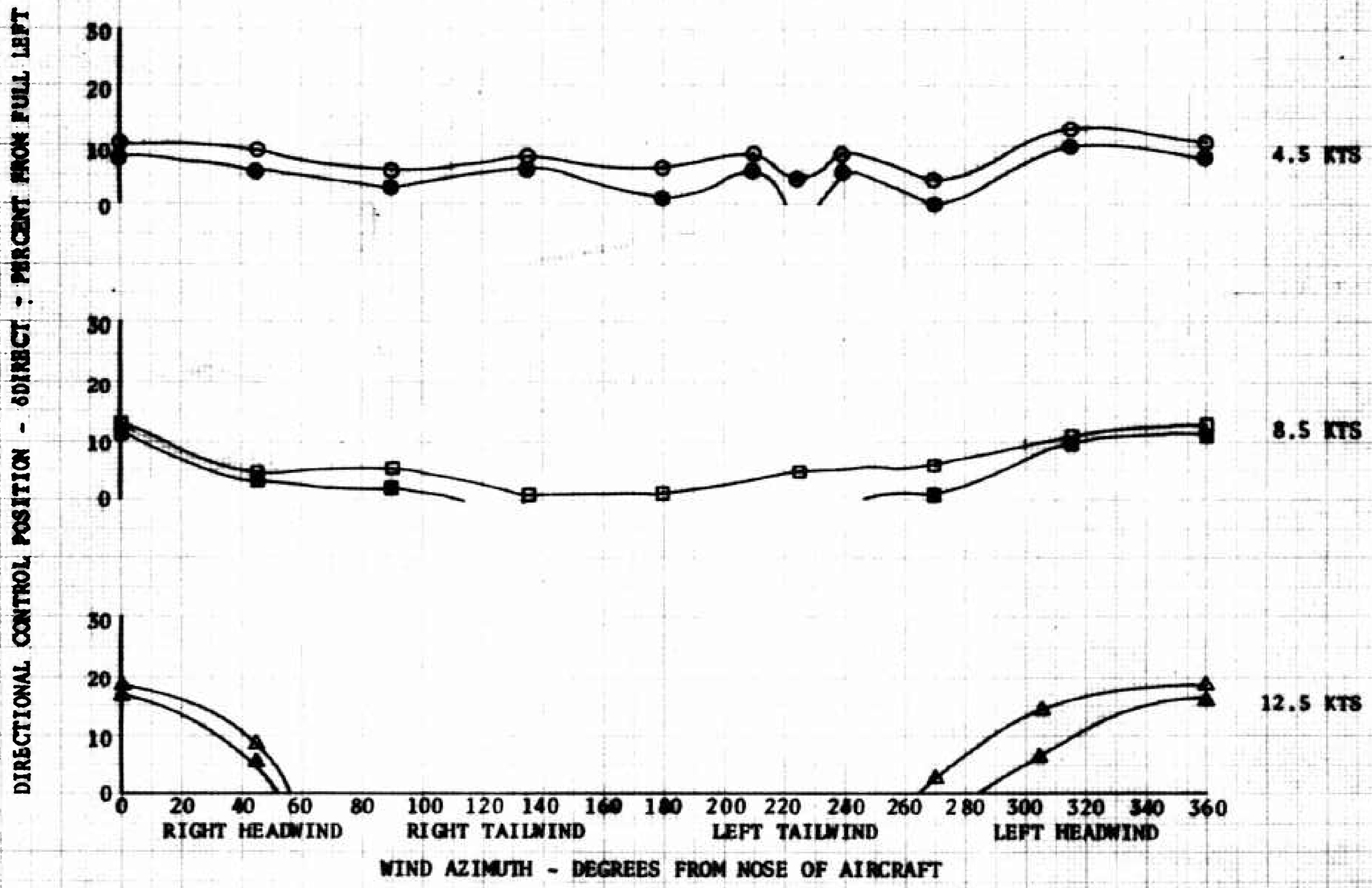
NOTE:
1. STANDARD TAIL ROTOR CONFIGURATION.
2. FULL LEFT DIRECTIONAL CONTROL = 19^{o} TAIL ROTOR PITCH.
3. OPEN SYMBOLS DENOTE MEAN DIRECTIONAL CONTROL POSITION REQUIRED TO STABILIZE AIRCRAFT.
4. SOLID SYMBOLS DENOTE MAXIMUM LEFT DIRECTIONAL CONTROL POSITION ENCOUNTERED WHEN STABILIZING AIRCRAFT.
5. TEST WAS CONDUCTED IGE AT AN AVERAGE SKID HEIGHT OF 10 FEET.

2

FIGURE NO 42
DIRECTIONAL CONTROL REQUIRED VS WIND AZIMUTH
AH-1G S/N 66-15247
HEAVY SCOUT CONFIGURATION

SYMBOL	ROTOR -RPM	G.W. -LB	C.G. - IN LONG	H_D FT	AIRSPEED - KTAS
○	324	7350	195.6 (MID)	10950	4.5
□	324	7210	195.4 (MID)	11090	8.5
△	324	7070	195.3 (MID)	11320	12.5

NOTE:
1. STANDARD TAIL ROTOR CONFIGURATION.
2. FULL LEFT DIRECTIONAL CONTROL = 19° TAIL ROTOR PITCH.
3. OPEN SYMBOLS DENOTE MEAN DIRECTIONAL CONTROL POSITION REQUIRED TO STABILIZE AIRCRAFT.
4. SOLID SYMBOLS DENOTE MAXIMUM LEFT DIRECTIONAL CONTROL POSITION ENCOUNTERED WHEN STABILIZING AIRCRAFT.
5. TEST WAS CONDUCTED IGE AT AN AVERAGE SKID HEIGHT OF 10 FEET.


DIRECTIONAL CONTROL POSITION - δDIRECT - PERCENT FROM FULL LEFT
30
20
10
0
4.5 KTS
8.5 KTS
12.5 KTS
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360
RIGHT HEADWIND
RIGHT TAILWIND
LEFT TAILWIND
LEFT HEADWIND
WIND AZIMUTH - DEGREES FROM NOSE OF AIRCRAFT

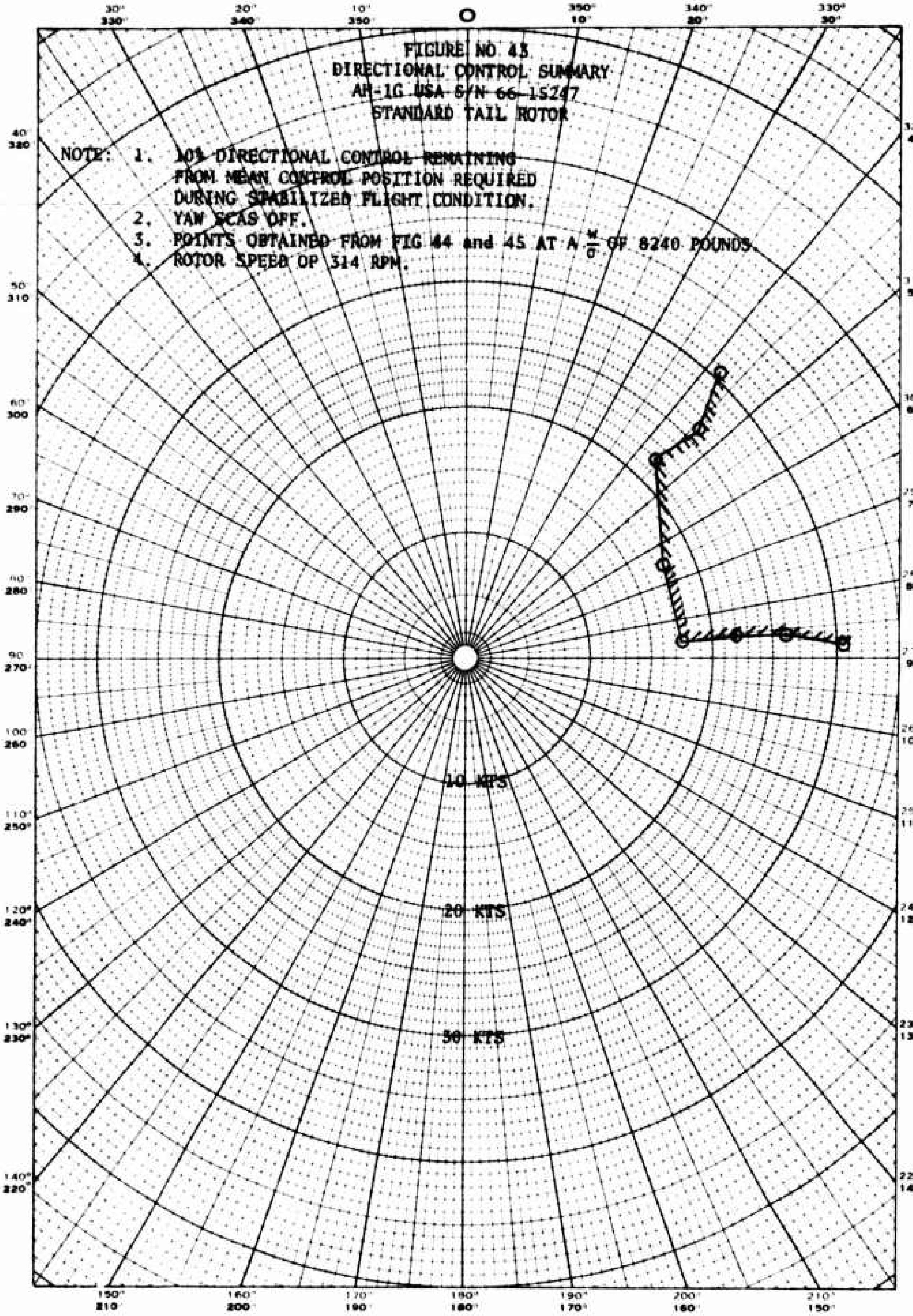


FIGURE NO. 43
DIRECTIONAL CONTROL SUMMARY
AH-1G USA S/N 66-15247
STANDARD TAIL ROTOR
NOTE: 1. 10% DIRECTIONAL CONTROL REMAINING FROM MEAN CONTROL POSITION REQUIRED DURING STABILIZED FLIGHT CONDITION.
2. YAW SCAS OFF.
3. POINTS OBTAINED FROM FIG 44 and 45 AT A W/σ OF 8240 POUNDS.
4. ROTOR SPEED OF 314 RPM.
10 KTS
20 KTS
30 KTS
0
30° 330°
20° 340°
10° 350°
350° 10°
340° 20°
330° 30°
40° 320°
50° 310°
60° 300°
70° 290°
80° 280°
90° 270°
100° 260°
110° 250°
120° 240°
130° 230°
140° 220°
320° 40°
310° 50°
300° 60°
290° 70°
280° 80°
270° 90°
260° 100°
250° 110°
240° 120°
230° 130°
220° 140°
150° 210°
160° 200°
170° 190°
180° 180°
190° 170°
200° 160°
210° 150°

FIGURE NO 44

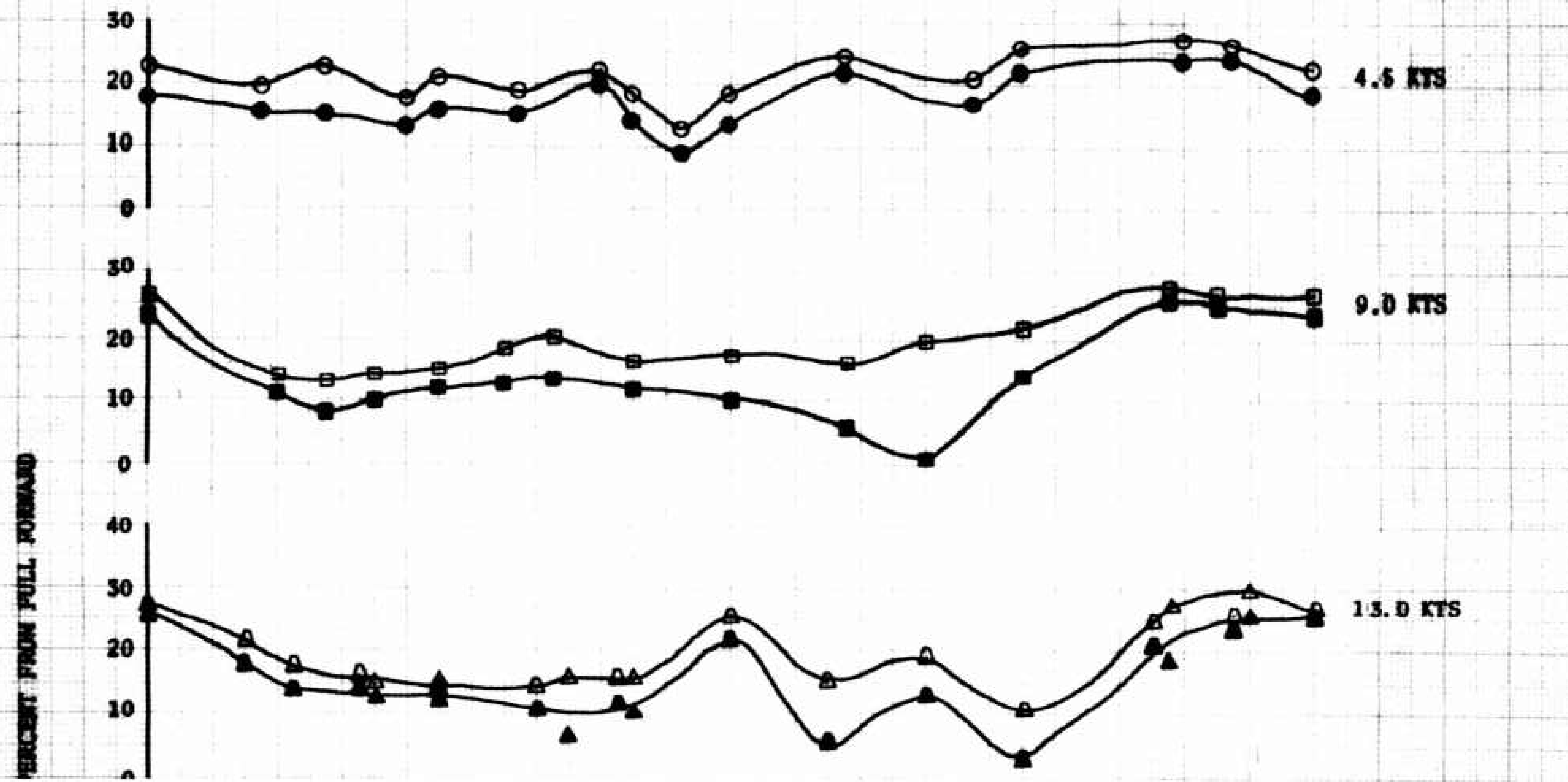
DIRECTIONAL CONTROL REQUIRED VS WIND AZIMUTH

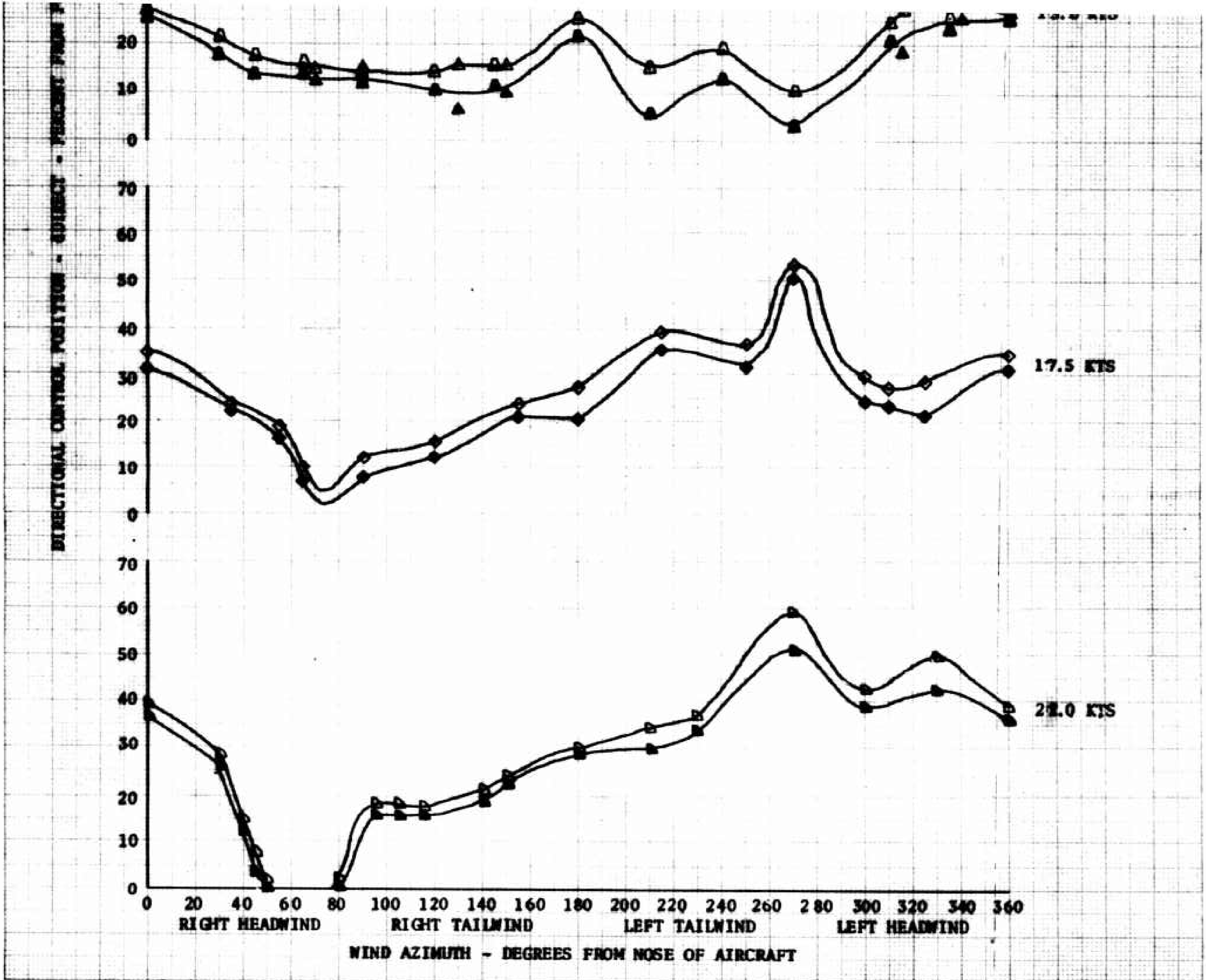
AH-1G S/N 66-15247

HEAVY SCOUT CONFIGURATION

SYMBOL	ROTOR - RPM	G.W. - LB	C.G. - IN LONG	H_D FT	AIRSPEED - KTAS
○	314	8080	200.9 (AFT)	570	4.8
□	314	8060	200.8 (AFT)	570	9.0
△	314	8040	200.8 (AFT)	570	13.0
△	314	8340	199.2 (AFT)	-400	13.9
◇	314	8360	199.0 (AFT)	-400	17.5
◁	314	8440	198.8 (AFT)	-400	22.0

NOTE:
1. STANDARD TAIL ROTOR CONFIGURATION.
2. FULL LEFT DIRECTIONAL CONTROL = 19° TAIL ROTOR PITCH.
3. OPEN SYMBOLS DENOTE MEAN DIRECTIONAL CONTROL POSITION REQUIRED TO STABILIZE AIRCRAFT.
4. SOLID SYMBOLS DENOTE MAXIMUM LEFT DIRECTIONAL CONTROL POSITION ENCOUNTERED WHEN STABILIZING AIRCRAFT.
5. TEST WAS CONDUCTED IGE AT AN AVERAGE SKID HEIGHT OF 10 FEET.





DIRECTIONAL CONTROL POSITION - SUBJECT - PERCENT FROM
17.5 KTS
21.0 KTS
0
10
20
30
40
50
60
70
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
RIGHT HEADWIND
RIGHT TAILWIND
LEFT TAILWIND
LEFT HEADWIND
WIND AZIMUTH - DEGREES FROM NOSE OF AIRCRAFT

FIGURE NO 45
DIRECTIONAL CONTROL REQUIRED VS WIND AZIMUTH
AH-1G S/N 66-15247
HEAVY SCOUT CONFIGURATION

SYMBOL	ROTOR - RPM	G.W. - LB	C.G. - IN LONG	H_p FT	AIRSPEED - KTAS
○	314	8340	198.7 (AFT)	-400	26.0
□	314	8290	198.7 (AFT)	-400	30.5

NOTE:
1. STANDARD TAIL ROTOR CONFIGURATION.
2. FULL LEFT DIRECTIONAL CONTROL = 19° TAIL ROTOR PITCH.
3. OPEN SYMBOLS DENOTE MEAN DIRECTIONAL CONTROL POSITION REQUIRED TO STABILIZE AIRCRAFT.
4. SOLID SYMBOLS DENOTE MAXIMUM LEFT DIRECTIONAL CONTROL POSITION ENCOUNTERED WHEN STABILIZING AIRCRAFT.
5. TEST WAS CONDUCTED IGE AT AN AVERAGE SKID HEIGHT OF 10 FEET.

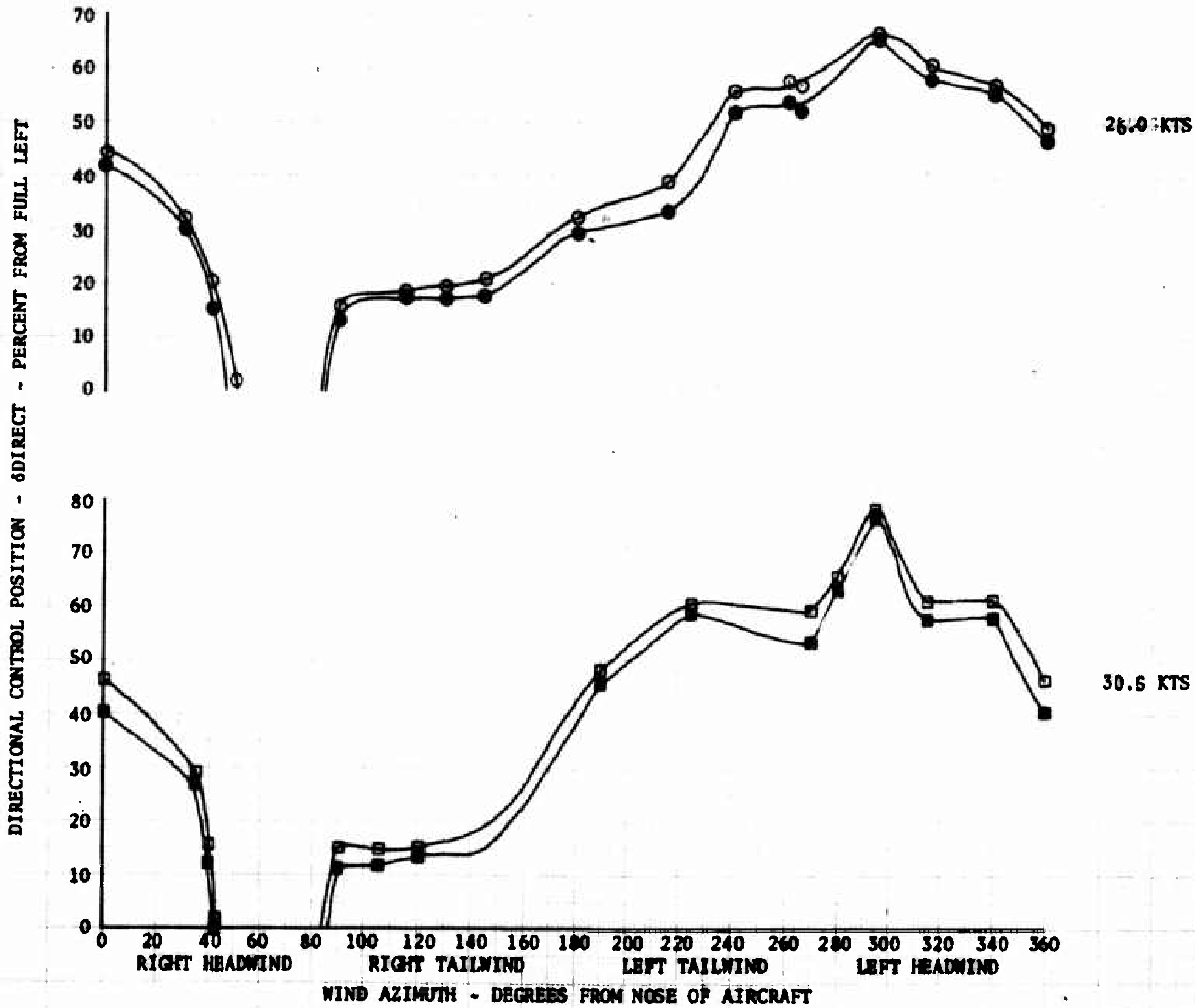


FIGURE NO 46
DIRECTIONAL CONTROL CAPABILITY
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR

GROSS WEIGHT ~ 7980 LBS
C.G. STATION ~ 192.9 IN
DENSITY ALTITUDE ~ 10, 510
CONFIGURATION ~ HEAVY SCOUT
FLIGHT CONDITION ~ HOVER

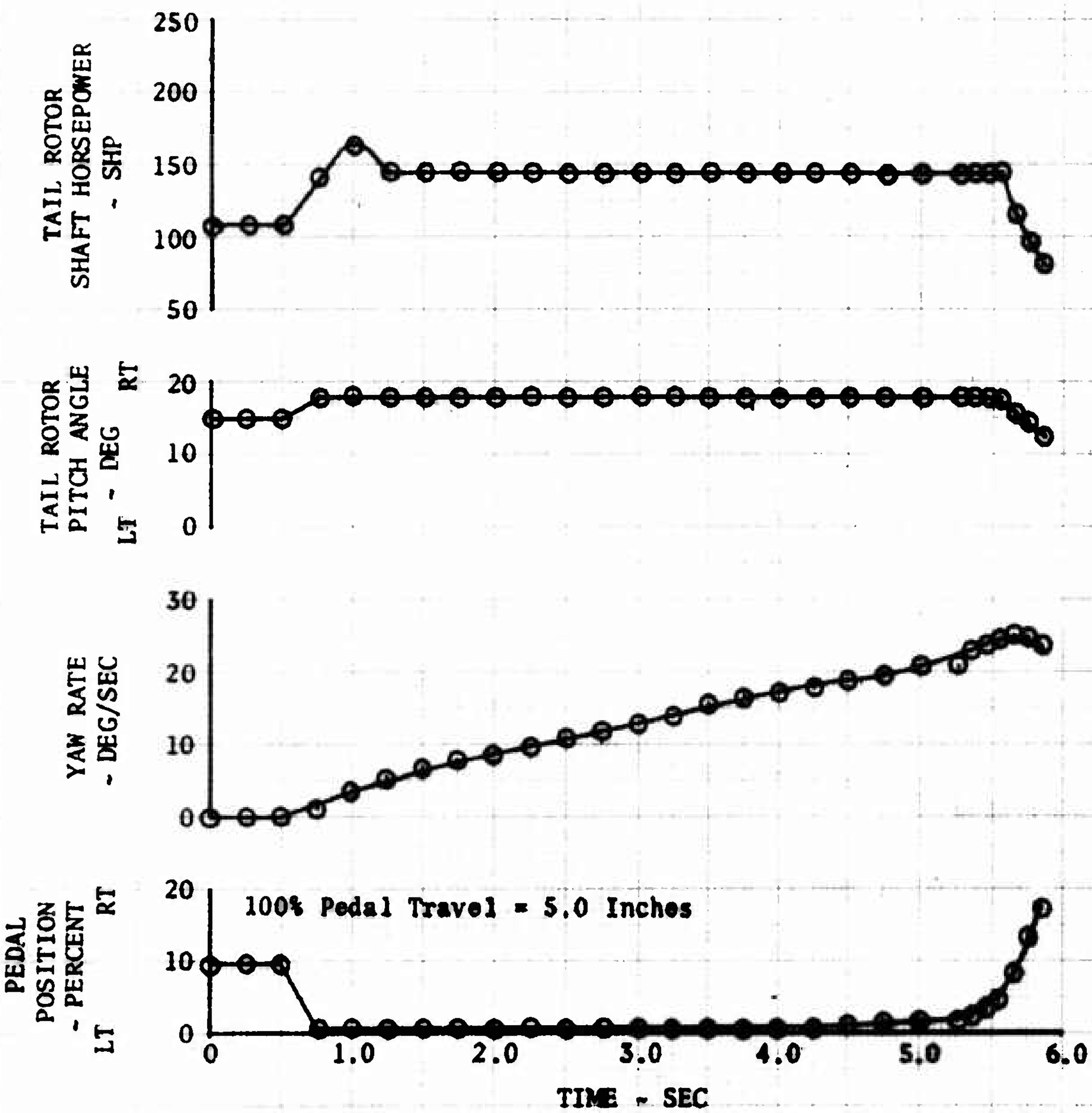


FIGURE NO 47
DIRECTIONAL CONTROL CAPABILITY
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR

GROSS WEIGHT	~	9035 LBS
C.G. STATION	~	194.2 IN
DENSITY ALTITUDE	~	5950 FT
CONFIGURATION	~	HEAVY SCOUT
FLIGHT CONDITION	~	RIGHT SIDEWARD
TRUE AIRSPEED	~	13 KNOTS

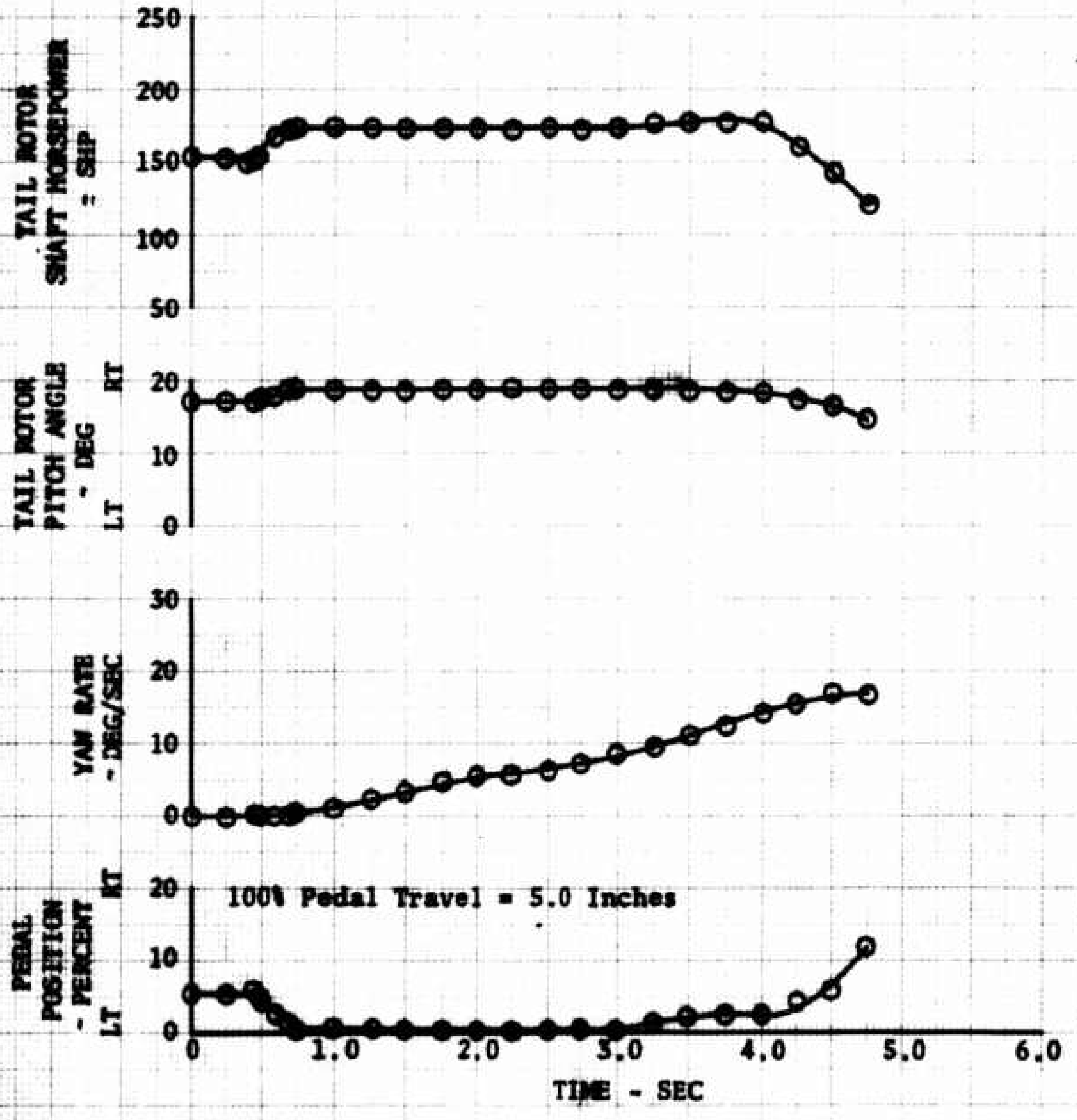


FIGURE NO 48
DIRECTIONAL CONTROL CAPABILITY
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR

GROSS WEIGHT ~ 8205 LBS
C.G. STATION ~ 192.0 IN
DENSITY ALTITUDE ~ 4080 FT
TRUE AIRSPEED ~ 20 KNOTS
CONFIGURATION ~ HEAVY SCOUT
FLIGHT CONDITION ~ RIGHT SIDEWARD

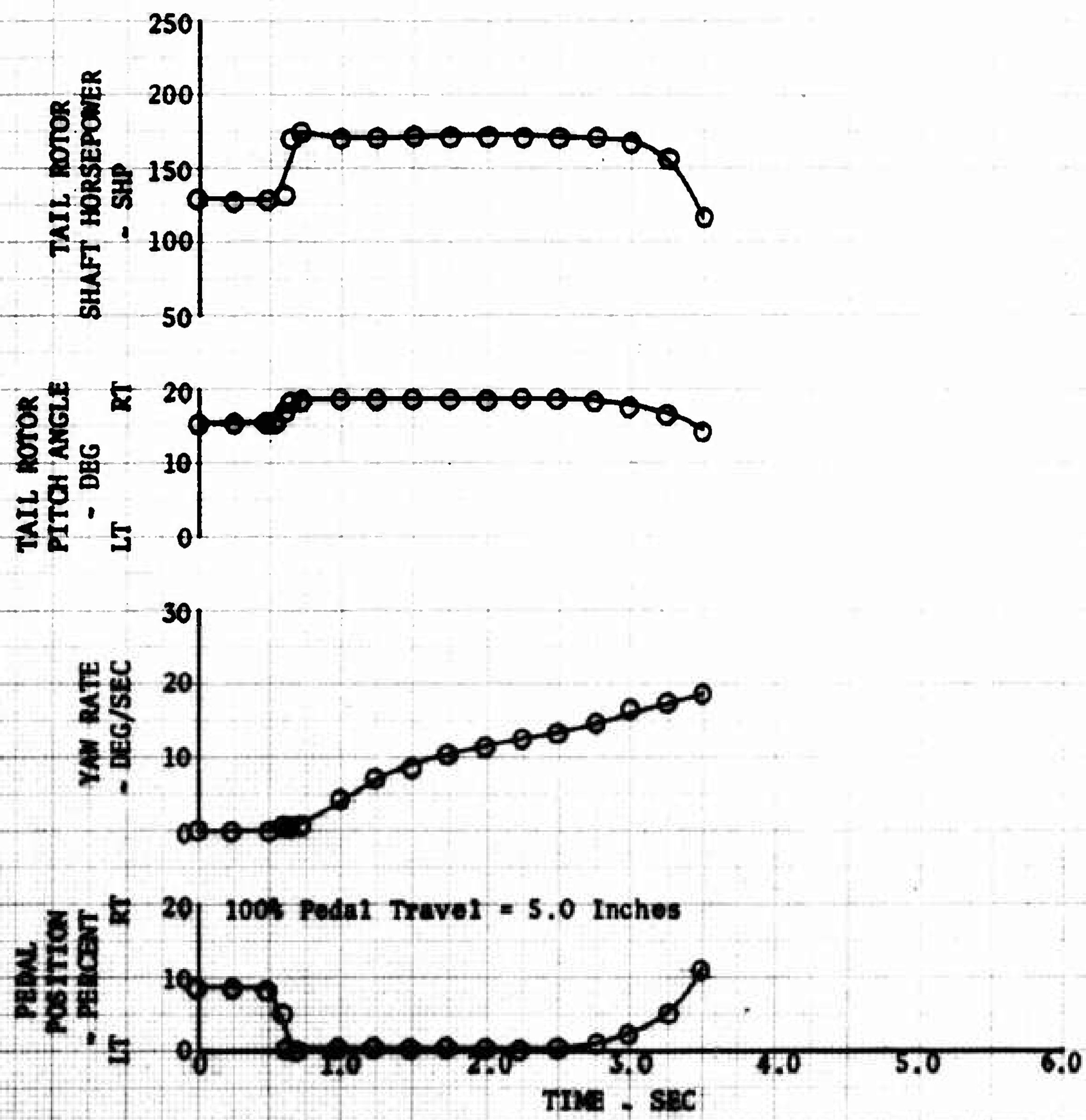


FIGURE NO 49
TURN ARRESTMENT IN HOVER
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR

GROSS WEIGHT	~	8100 LBS
C.G. STATION	~	200 IN
DENSITY ALTITUDE	~	3620 FT
ROTOR SPEED	~	324 RPM
CONFIGURATION	~	HOG
INITIAL YAW RATE	~	21.1 DEG/SEC

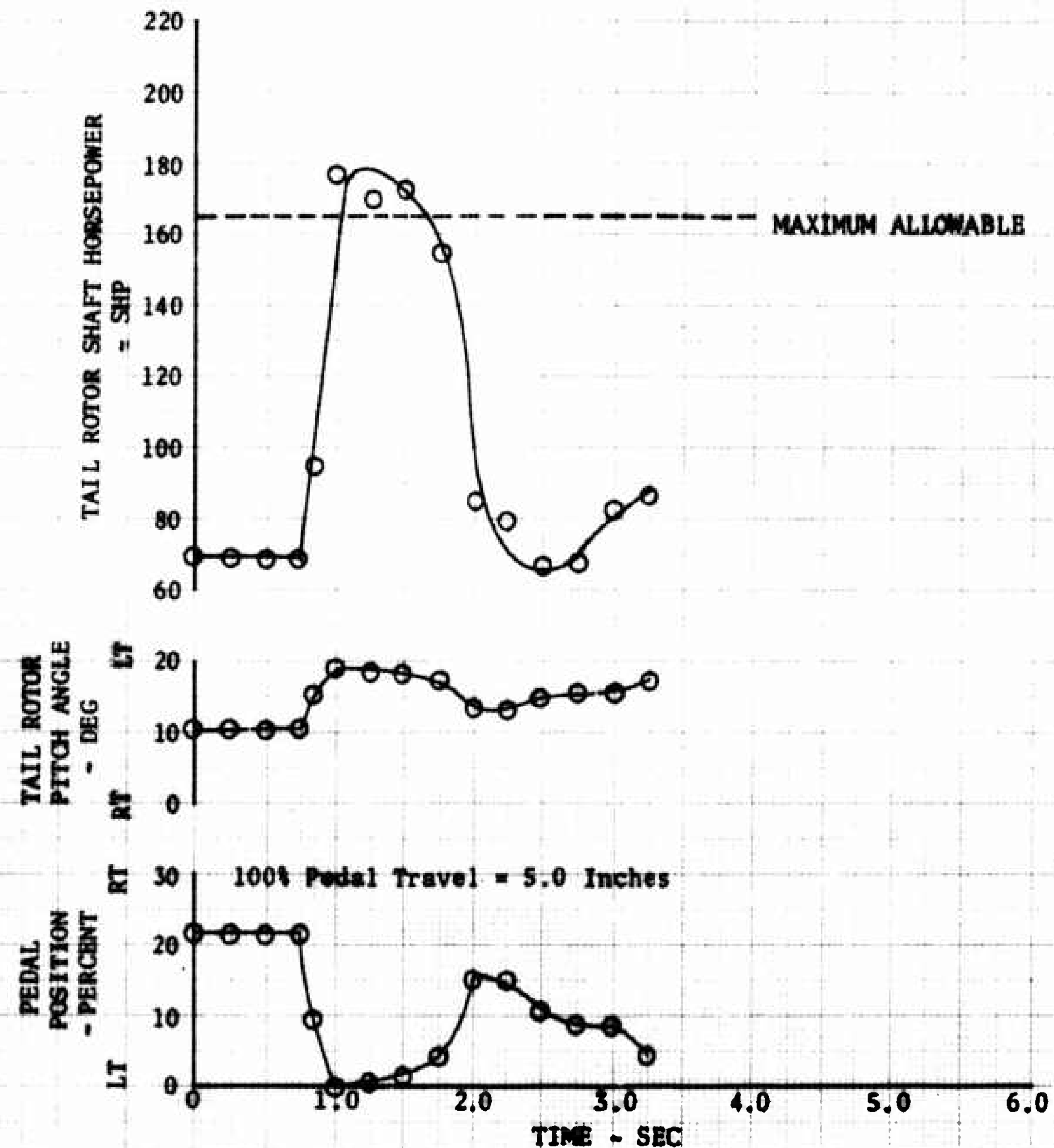


FIGURE NO 50
TURN ARRESTMENT IN HOVER
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR

GROSS WEIGHT	~	9100 LBS
C.G. STATION	~	196.8 IN
DENSITY ALTITUDE	~	4280 FT
ROTOR SPEED	~	324 RPM
CONFIGURATION	~	HOG
INITIAL YAW RATE	~	21.5 DEG/SEC

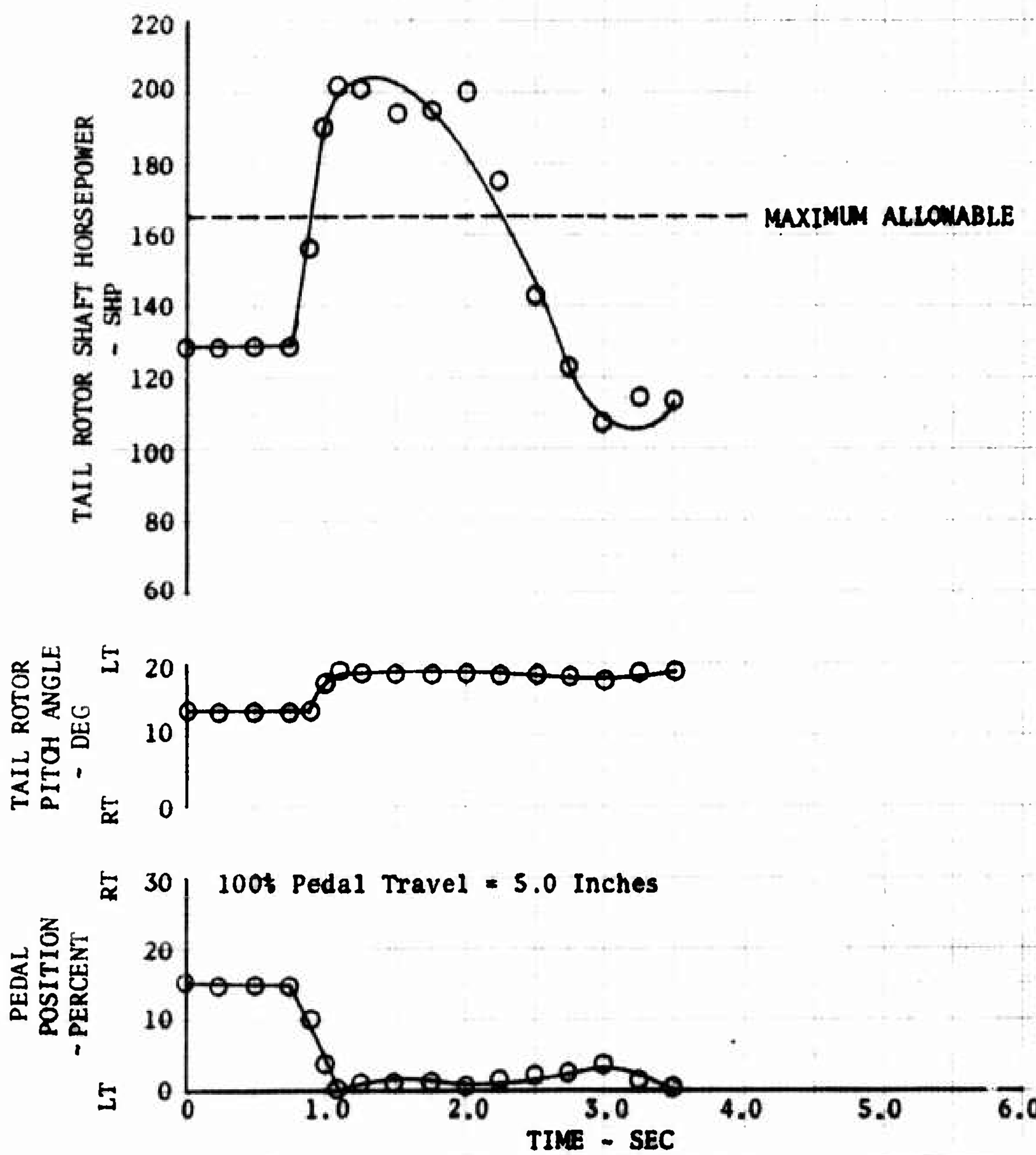


FIGURE NO 51
TURN ARRESTMENT IN HOVER
AH-1G USA S/N 66-15283
TRACTOR TAIL ROTOR

GROSS WEIGHT	~	9090 LBS
C.G. STATION	~	196.8 IN
DENSITY ALTITUDE	~	4280 FT
ROTOR SPEED	~	324 RPM
CONFIGURATION	~	HOG
INITIAL YAW RATE	~	30.9 DEG/SEC

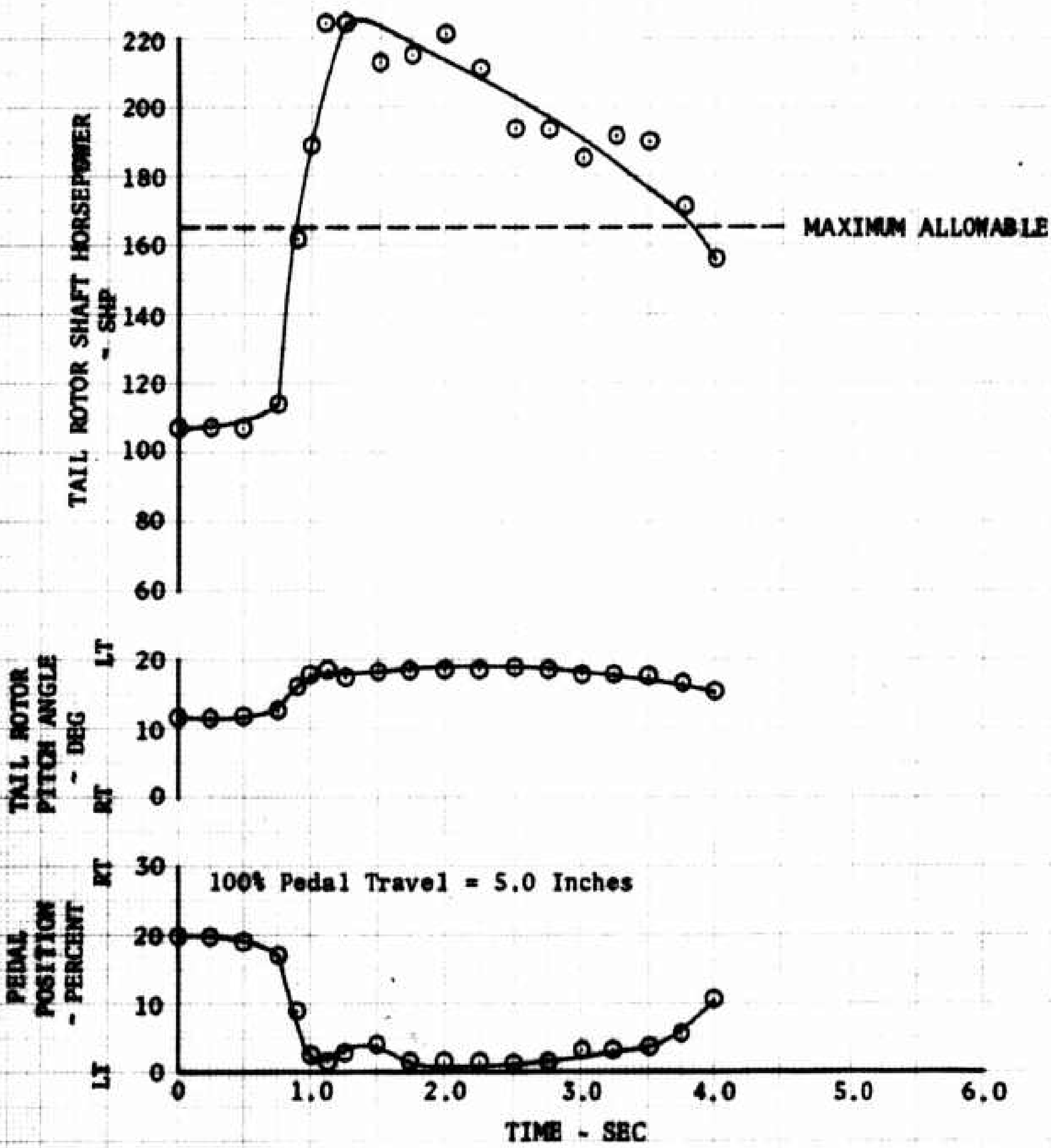
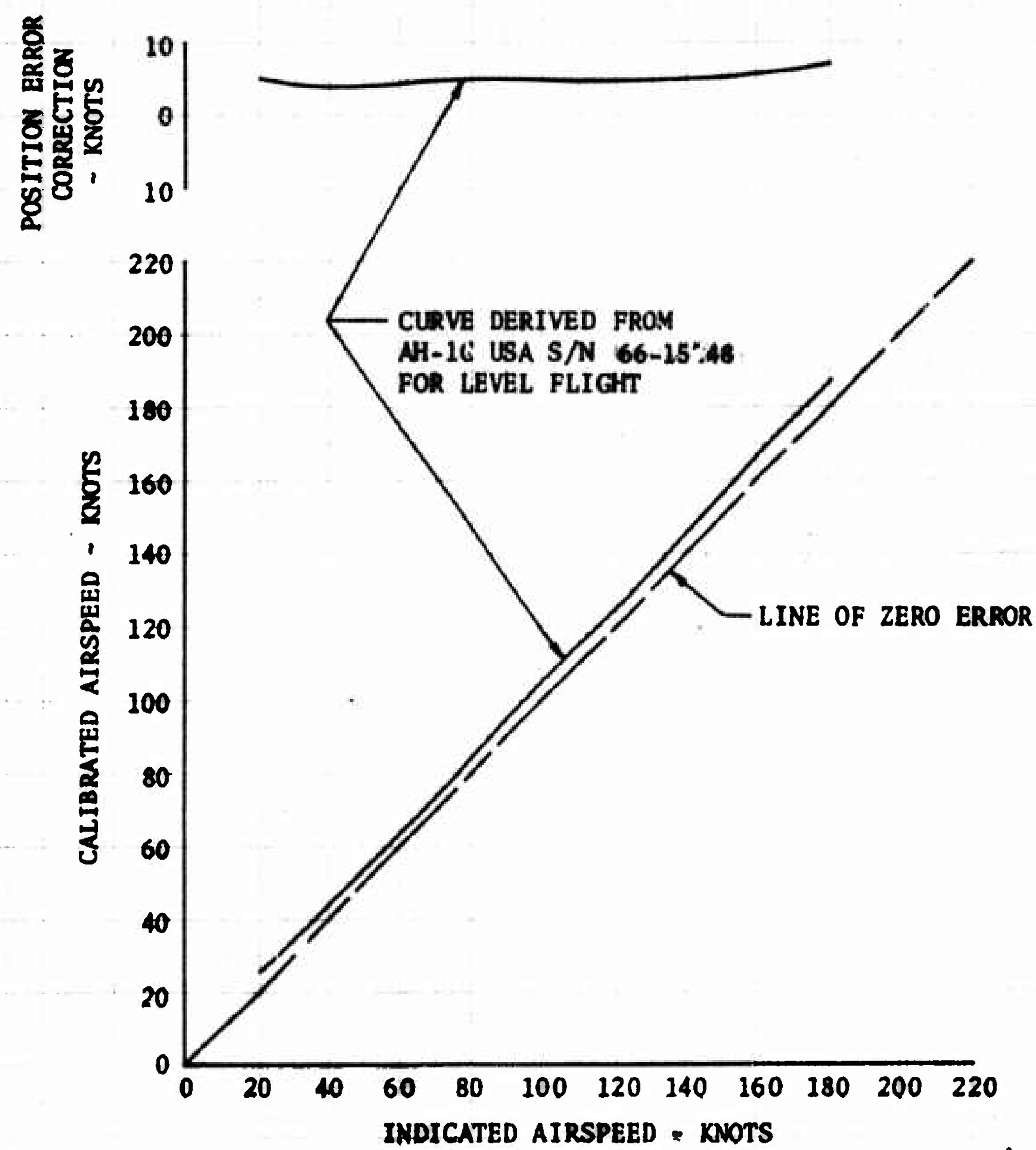


FIGURE NO 52
AIRSPEED CALIBRATION
AH-1G USA S/N 66-15283
BOOM SYSTEM



APPENDIX III. TEST INSTRUMENTATION

1. Flight test instrumentation was installed in the test helicopter by the contractor prior to the start of this evaluation with the exception of the fuel flow counter. The counter was calibrated and installed by USAAVNTA personnel. The flight test instrumentation was maintained by the USAAVNTA personnel with assistance from the contractor instrumentation engineer during the test program. The following parameters were utilized during the various tests:

Cockpit Panel

- Airspeed (boom)
- Altimeter (boom)
- Outside air temperature
- Tail rotor torque
- Sensitive rotor tachometer
- Fuel counter
- Sideslip angle
- Pedal position gage
- Record counter

Photopanel

- Airspeed (boom)
- Altimeter (boom)
- Outside air temperature
- Fuel counter
- Exhaust gas temperature
- Gas producer speed
- Dual tachometer
- Record counter

Oscillograph

- CG vertical acceleration
- Engine delta torque pressure
- Tail rotor shaft torque
- Main rotor and tail rotor azimuth
- Longitudinal cyclic position
- Lateral cyclic position
- Collective stick position
- Longitudinal SAS actuator position
- Lateral SAS actuator position
- Directional SAS actuator position
- Tail rotor flapping position
- Throttle position
- Pedal position
- Pitch attitude gyro
- Roll attitude gyro
- Yaw attitude gyro
- Pitch rate gyro
- Roll rate gyro
- Yaw rate gyro
- Tail rotor pitch angle
- Angle of attack
- Angle of sideslip

APPENDIX IV AH-IG OPERATING LIMITATIONS

Limit Airspeed (V_L)

1. Hog configuration - 180 KCAS below 3000 feet density altitude. Decrease 8 KCAS per 1000 feet above 3000 feet.

2. Basic and Scout configurations - 190 KCAS below 4000 feet density altitude. Decrease 8 KCAS per 1000 feet above 4000 feet.

Gross Weight - Center of Gravity Envelope

3. Forward Limit - Below 7000 pounds, fuselage station (FS) 190. Linear decrease from FS 190 at 7000 pounds to FS 192.1 at 9500 pounds.

4. Aft Limit - Below 8270 pounds, FS 201. Linear decrease from FS 201 at 8270 pounds to FS 200 at 9500 pounds.

Sideslip Limits

5. Five degrees at V_L. Linear increase to 25 degrees at 60 KCAS.

RPM Limits (steady state)

6. Power on - 6600 to 6400 engine rpm
324 to 314 rotor rpm

7. Power on - 319 to 324 rpm
during dives and maneuvers

8. Power off - 304 to 339 rotor rpm
250 rotor rpm transient lower limit

Temperature and Pressure Limits

Engine oil temperature	93°C maximum
Engine oil pressure	25 psi minimum - 100 psi maximum

APPENDIX V. PILOT RATING SCALE

CONTROLLABLE CAPABLE OF BEING CONTROLLED OR MANAGED IN CONTEXT OF MISSION, WITH AVAILABLE PILOT ATTENTION	ACCEPTABLE MAY HAVE DEFICIENCIES WHICH WARRANT IMPROVEMENT, BUT ADEQUATE FOR MISSION. PILOT COMPENSATION, IF REQUIRED TO ACHIEVE ACCEPTABLE PERFORMANCE, IS FEASIBLE.	SATISFACTORY MEETS ALL REQUIREMENTS AND EXPECTATIONS, GOOD ENOUGH WITHOUT IMPROVEMENT CLEARLY ADEQUATE FOR MISSION.	EXCELLENT, HIGHLY DESIRABLE	A1
			GOOD, PLEASANT, WELL BEHAVED	A2
			FAIR. SOME MILDLY UNPLEASANT CHARACTERISTICS. GOOD ENOUGH FOR MISSION WITHOUT IMPROVEMENT.	A3
		UNSATISFACTORY RELUCTANTLY ACCEPTABLE. DEFICIENCIES WHICH WARRANT IMPROVEMENT. PERFORMANCE ADEQUATE FOR MISSION WITH FEASIBLE PILOT COMPENSATION.	SOME MINOR BUT ANNOYING DEFICIENCIES. IMPROVEMENT IS REQUESTED. EFFECT ON PERFORMANCE IS EASILY COMPENSATED FOR BY PILOT.	A4
			MODERATELY OBJECTIONABLE DEFICIENCIES. IMPROVEMENT IS NEEDED. REASONABLE PERFORMANCE REQUIRES CONSIDERABLE PILOT COMPENSATION.	A5
			VERY OBJECTIONABLE DEFICIENCIES. MAJOR IMPROVEMENTS ARE NEEDED. REQUIRES BEST AVAILABLE PILOT COMPENSATION TO ACHIEVE ACCEPTABLE PERFORMANCE.	A6
	UNACCEPTABLE DEFICIENCIES WHICH REQUIRE MANDATORY IMPROVEMENT. INADEQUATE PERFORMANCE FOR MISSION EVEN WITH MAXIMUM FEASIBLE PILOT COMPENSATION.		MAJOR DEFICIENCIES WHICH REQUIRE MANDATORY IMPROVEMENT FOR ACCEPTANCE. CONTROLLABLE. PERFORMANCE INADEQUATE FOR MISSION, OR PILOT COMPENSATION REQUIRED FOR MINIMUM ACCEPTABLE PERFORMANCE IN MISSION IS TOO HIGH.	U7
			CONTROLLABLE WITH DIFFICULTY. REQUIRES SUBSTANTIAL PILOT SKILL AND ATTENTION TO RETAIN CONTROL AND CONTINUE MISSION.	U8
			MARGINALLY CONTROLLABLE IN MISSION. REQUIRES MAXIMUM AVAILABLE PILOT SKILL AND ATTENTION TO RETAIN CONTROL.	U9
UNCONTROLLABLE CONTROL WILL BE LOST DURING SOME PORTION OF MISSION.			UNCONTROLLABLE IN MISSION.	10

APPENDIX VI. DISTRIBUTION

Agency	Test Plans	Equipment Failure Reports	Interim Reports	Final Reports
Commanding General				
US Army Aviation Systems Command				
ATTN: AMSAV-R-F	5	2	5	15
AMSAV-R-FT	3	2	3	3
AMSAV-C-A	-	-	2	2
AMSAV-L-F	-	-	-	1
AMSAV-R-EH	2	2	2	2
AMSAV-C-W (weapons only)	2	-	-	2
AMSAV-R-R	-	-	-	1
PO Box 209				
St. Louis, Missouri 63166				
Commanding General				
US Army Materiel Command				
ATTN: AMCPM-IR	5	1	1	5
PO Box 209				
St. Louis, Missouri 63166				
Commanding General				
US Army Materiel Command				
ATTN: AMCRD	2	1	1	2
AMCAD-S	-	-	-	1
AMCPP	-	-	-	1
AMCMR	2	-	-	2
AMCQA	-	-	-	1
Washington, D. C. 20315				
Commanding General				
US Army Combat Developments Command				
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13. ABSTRACT

The Army Preliminary Evaluation of the tractor tail rotor modification on the AH-1G helicopter was conducted in California at Bishop Municipal Airport (4000 ft) and Coyote Flats (9500 ft) during the period 9 August to 31 August 1968. This test was conducted to confirm the results of the feasibility tests with the proposed final configuration for this modification and also to evaluate both the performance in hover and level flight and the handling qualities throughout the flight envelope. This modification provides an increase in the usable in-ground-effect (IGE) operating envelope and improves the directional control characteristics while maneuvering. The test showed good agreement with the results of the earlier feasibility tests. The maximum safe IGE maneuvering envelope for the tractor tail rotor AH-1G was determined and defined by those conditions of gross weight and density altitude where a 10-percent directional control margin was available in the critical azimuth in a 15-knot wind. Using the same criteria for the standard AH-1G configuration, the difference due to the improved directional control with the tractor tail rotor is equivalent to an additional 1500 pounds

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AH-1G helicopter						
Tractor tail rotor modification						
Confirm results						
Feasibility tests						
Proposed final configuration						
Performance						
Handling qualities						
Flight envelope						
Increase						
In-ground-effect operating envelope						
Improves						
Directional control						
While maneuvering						
Maximum envelope determined						
Additional payload						
Basic directional control						
Problem not solved						

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